MASTER THESIS

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Universal Design of ICT

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< Development and Evaluation of Mobile Touch-Based Interaction Prototype in the Context of Universal Design >

<Rao Muhammad Danial Ali>

Department of Computer Science

Faculty of Technology, Art and Design

OSLO AND AKERSHUS
UNIVERSITY COLLEGE
OF APPLIED SCIENCES

Preface

The thesis was written as a fulfillment of the Master in Universal Design of Information Communication Technology (ICT) at Oslo University College. First of all, I would like to offer thanks to my supervisor Dr. Pietro Murano, his immaculate knowledge and command on the subject of Human Computer Interaction (HCI) guided me throughout the project. I would also thank Faculty of Engineering, Art, and Design of (TKD) department for making me feel welcomed during my stay at Oslo and Akershus University College.

I also offer many thanks to accessibility research community whose ideas helped me during my research and strengthened my believe in collaboration. Researchers from the Universal Design of ICT and I share the same goal of making the world equally accessible for everyone by improving ICT solutions.

Furthermore, I would like to thank Siri Kessel who introduce me to this valuable course and her valuable suggestions. Thanks a lot to my friends, Syed Moiz Hassnain for understanding, supporting and proofreading.

Last but not least, my family parents and my uncle and aunty for believing in me. Without their support, it would not be possible to achieve this important milestone of my life.

Rao Muhammad Danial Ali

Master Student

Abstract

Force touch gesture is widely used in desktop and laptop computers, but newly designed 3D touch gesture introduced first time in the mobile interface by Apple with pressure properties, but it has many accessibility issues for vision and fine motor impaired people.To address the need for a universal and accessible mobile touch gesture, we have designed and evaluate universally designed mobile touch screen gestures prototype for the elderly friendly interface. The specification gathers from the Universal Design Principle and newly purposed WCAG 2.1 conformance level for touch interface including pressure properties. We evaluated the accessibility of our prototype with an elderly population with mixed kind of impairments due to aging and with no impairments. The proportion of the participants were divided between novice and expert touch screen users and had mixed user experienced for pressure based touch gesture with both positive and negative reactions. This study confirmed the WCAG 2.1 Accessibility conformance level with ATs and extraordinary environments. This research helps to understand the elderly people requirements, concerns, and emotions about the new interface. The results show that the participant's performance was improved in some tasks. Participants suggested that alternative gestures with some improvement can be useful in future for mobile interactions.

Contents

1 Introduction

This master thesis starts with the idea "how force touch gesture plays its role in future mobile computing for elderly people.". For this, we have followed the technology probe method which means simple, adaptable, flexible technologies define by (Lazar, Feng, & Hochheiser, 2010a) which have three goals understanding the older adults needs and desires, field-testing the force touch technology and provide purpose solutions to inspire older adults and researcher to think about this future gesture by developing these gesture with Universal Design Principles in mind.

The popularity of touchscreen devices is increasing day by day. There are different kinds of touch screen mobile devices available which we have discussed in the literature review in details. The accessibility community has been foreseeing the usage of these high-end technologies by different user groups with their user experience perspective. Like every new technology, the use of force touch gesture also has the potential for both utopian and dystopian future. Subsequently, it is necessary for the accessibility community to design and develop force touch gestures using updated guidelines to thrive in the future.

In this study, we present the experimental results and methodology deployed in force touch-based gesture design for mobile computing. The initial results show that older adults users are satisfied with the force touch gesture, Users encounter numerous barriers while using touch screen gestures under different conditions in daily routine. The most common issues faced by older users are the small touch screen size and the precision required for an interactive experience. Also, such users can often move their fingers relatively slowly (Kim & Jo, 2015). We thoroughly inspected the guidelines defined by WCAG about mobile gestures, and researcher like (Ruzic, Lee, Liu, & Sanford, 2016), who developed guidelines for Universal Design Mobile Interface for older adults. This thesis examines the performance of the prototype to measure the cognitive and physical load on senior users while using force touch gestures. This research qualitatively analyzed the patterns and techniques used by the users to learn new interaction methods, which will be very common in future mobile usage.

The aim of this prototype is to design a user interface with a Universal Design principle for older users. The motive is to overcome the obstacles faced by this group while using touch screen devices in their daily routine.

Initially, we design a web page which supports force touch gesture as a feature. We anticipated that if older adults can use this gesture on a web page, they may be motivated to use force gestures in another environment like mobile applications rather easily.

This phase of the thesis is based on experiments to understand force touch-based gestures by a performance with two interaction techniques: one for zooming, and the other for rotating. We analyzed the gestures qualitatively through both interviews, and observation of the participants.

The qualitative method was applied to get the user experience.The questions were designed with the help of the art of focused conversation by Stanfield (2000). Because this conversation in the data collection needs to be more organized and well structured. The interviews helped us to understand user perspective on the daily use of mobile technology; responses showed that mobile interface has lots of accessibility issues. It also helped us to study user experience of force touch in the daily mobile computing for older adults. Furthermore, we tried to gain acquire knowledge about accessibility and usability issues faced by this group and established ways to improve newly designed force-gesture for the touch screen.

Smart Phone usage has had explosive growth in past few years, and new ICT solutions can be transferred from desktop computers to smartphones, which implies that more mobile based applications shall be introduced in upcoming years(Findlater, Froehlich, Fattal, Wobbrock, & Dastyar, 2013). As smart devices continue to expand different interaction styles than traditional computers, the demand for a new dimension of functionality is growing. Newly invented interaction methods have a different usability and accessibility issue, which needs to be explored, evaluated and redesigned. These new types of interaction include alternative methods of input so more users can benefit from them, such as the elderly, or people who have any impairment. On the other hand, the advancement of touch screen technology contributes to encouraging older people to use ICT systems for social participation.

The spirit of universal design and its principle helps us to develop an Elderly Friendly mobile interface. This, in turn, which helps them in performing their touch operations successfully.

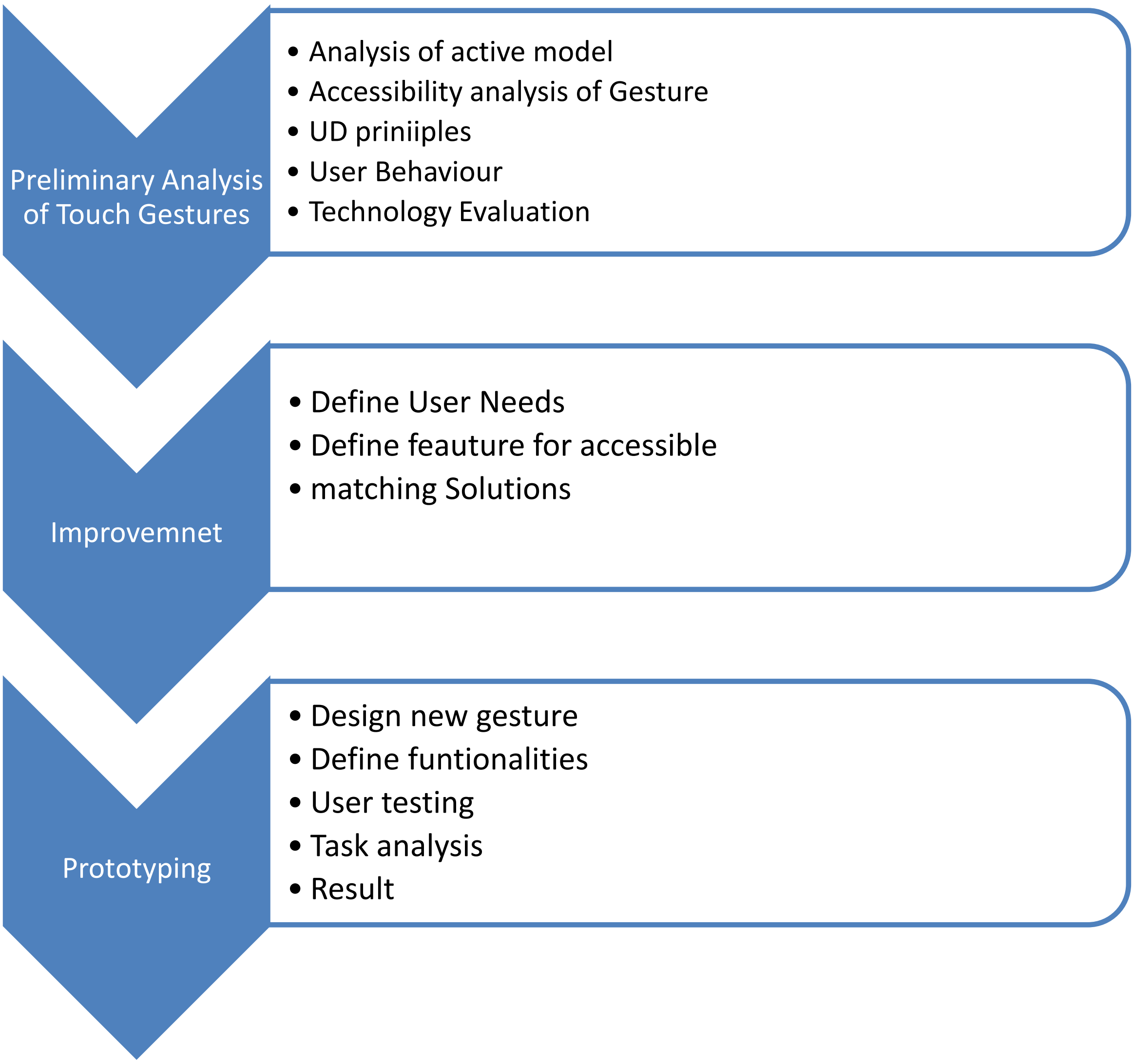
Touch screen interface is gaining popularity. Researchers and developers continuously work on the best interaction methods to make solutions easier for all kind of users. Now, researchers are trying to find out the best possible methods for improving user interface by utilizing all of the possible input and output methods of touch screens. Researchers are also finding new ways of interaction with touch screens, including assistive technology, like the stylus, screen readers, and voice recognition, making interaction more ubiquitous. Touch screens require many defined and predefined gestures(Bhalla & Bhalla, 2010); it is observed that the big platform like Apple and Andriod the gesture are different for the same task. It is good opportunity for the researcher to designed force touch gesture universally designed in mind so the user can switch from one platform to another easily. Universal Design and WCAG principle about consistency in layout help designer to develop same gesture for the same task, so a new user does not need to learn gesture from scratch. The gesture-based interaction is the main part of creating natural human-computer interaction. Gestures in mobile interactions help the elderly people user to overcome accessibility and usability (Findlater et al., 2013). Multi-touch gestures, like tap, swipe, and pinch, are very useful for touch screen interaction. People who have any impairment try to avoid barriers by finding alternative ways of doing the same task through different inputs. Multi-touch interactions help the user to act on the touch screen in their natural way.

The pressure gesture, which is newly introduced in mobile technology, works such that the device senses the amount of pressure exerted by the human finger on a touch screen(Rekimoto & Schwesig, 2006). These kinds of gestures are new and need to be investigated by accessibility and usability testing to improve the user interface.

Apple (3D-Touch) is the new way of using haptic feedback through the screen so that it feels like it has real buttons on it. This is an example of how force touch-based interactions can increase the accessibility and usability of touch screens for users with visual and motor impairments. This study helps us to understand the role of pressure based touch gestures as an alternative mode of interaction with touch interfaces.

1.1 Objective

Table 1 Objective



This study begins with probing the new ideas of possible gesture with force touch technology. Which need a literature review of what research has been done to enhance touchscreen accessibility and usability so far. We did a systematic review by collecting the research papers which have the same area of research with Universal Design and Design for Ageing Guide-lines.This entails studying previous works regarding how force touch interaction with mobile technology currently function, and creating a list of what is important to focus on, including, but not limited to, usability and accessibility testing. The next step is focused on how to design research with suitable methods. This will be done by including research method approaches for data collection and data analysis which helps to create a prototype application for elderly or impaired people. We have designed our prototype with Wizard-of-Oz approach inspired by the research done by (Qiu, Rauterberg, & Hu, 2016). This approach simulates the touch gestures which are not really available in a smartphone.

This means testing the prototypes through in the field in real environment setting. The results and analysis from the test will be inspired researchers to think about the force touch technology for future interaction methods

1.2 Problem Statement

1.3 Background

The HCI researcher and practitioners continue working on the user interface which is appealing to older adults.we have found many studies in a literature review on touch-based interactions on all kinds of touchscreens, from vertical to horizontal, and from big to small screens. Researchers have tried to identify usability and accessibility issues with assistive technology. The main problem in touch screen-based gestures is interaction modalities, gaps of implementation of UD principles and guidelines, enabling technologies and the role of (3D-Touch)three-dimensional or force in gestures design for the touch screen. The study is based on the Universal Design and WCAG principles, which are related to force touch gestures. It is impractical to test force touch gesture with each and every guideline in a single study. We have run the query analysis in Nvivo to find out the most important guideline should be focused when developing new gestures and evaluate them in the field test. Our semi-structure interview session tries to question from each participant about the individual experience related to accessibility and usability.

The study is about the to track accessibility improvements in the touch gesture interface for elderly adults. The technologies are getting an advance but implementing the accessibility is very slow.

Innovation in human-computer interaction shows that future technologies will enable their users to interact with interfaces with more natural and intuitive ways, despite the fact that users are more comfortable with old, traditional ways of mouse and keyboard interaction(Komischke, 2011). New applications on mobile platforms should be designed with an interface that is accessible available for older people. Gestures should be easy to perform, and easy to remember by all kinds of users. The gesture should be designed in a natural way so users can easily learn and adopt them. The main challenges in this field are to minimize the mental load on the user regarding usability and accessibility aspects.

The following project has been developed for designing and evaluating new touch interaction in the field of human-computer interaction with the implementation of (3D-Touch)Three-dimensional touch on touch screen devices. This exploratory research has a goal to investigate the opportunities that these touch interactions offer because of their diverse use for their users, especially elderly adults. For the current research, I have developed two alternative three-dimension gestures and investigated the users' experience in different tasks performed. This project resulted in two prototypes that were evaluated using both user tests, as well as heuristic evaluation. The evaluation showed that one of the prototypes was preferred because it was more similar to existing solutions. In this phase, I performed manual accessibility and usability testing of the touch interactions. I tried my level best in completing this research in a successful manner.

The goal is to gain insight into how to design force touch gestures for mobile applications. This can be studied by defining usability and accessibility, and how to evaluate the usability of gestures, and then to consider how force touch helps users to minimize problems. We can also study the advantages and disadvantages of force touch.

Mobile platforms are very limited regarding user inputs as compared to laptops and computers Chang, L'Yi, Koh, and Seo (2015). Researchers and UX designers are trying to find new and better ways of interacting with the mobile devices. On the contrary, developers are working to use the best available input methods while developing applications and trying to take advantage of strengths and avoid weaknesses.

1.4 Problem Description

1.5 Statement of the Problem

Force touch gesture is newly introduced in mobile interaction. This study investigates how Universal Design Principles make force touch gesture as an alternative way of multi-touch gesture.

1.6 Problem Statement

This study investigates the force touch gesture user experience with older adults. As a study of Liang and Lee (2016) review that gestures like pinch, swap, and drag are difficult for older adults to remember and perform because of its need high precision to perform the task and demands excellent abilities of perception, cognition, and psychomotor. That is why developer needs to design gesture as simple and intuitive, and it can be possible by following Universal Design Principles and WCAG Guidelines.

Many researchers investigating on accessibility and usability for touch screen interactions. For instance, Godinho, Condado, Zacarias, and Lobo (2015), shows that users with motor impairment have trouble with the mobile interfaces due to screen size. Their study shows that older people who have any motor impairment have longer response times as compared to younger individuals who have better motor abilities. Where response time is the amount of time, they took to complete the task. The solution, EasyWrite by Godinho et al. (2015), helps the touch screen user recognize the content on a screen through haptic and vibrator based feedback. Godinho et al. (2015) suggested that mobile application developers could benefit from universal design principles, utilizing alternative inputs like tactile, acoustic and feedback with “Design for All.”

Gao and Sun (2015)Purposed a solution called “fisheye function for users who have a motor impairment. Lots of research shows that people who have motor impairments have an issue with interactions on the touch screens, especially when they have to perform gestures to complete a task. Their main contribution of the studies shows that user prefers pressure based gestures over multi-touch input. In their experiment, they conduct research to compare multi-touch gestures with pressure based gestures where the participants perform tasks like zooming in and zooming out on a picture viewer application on Personal Computer (HP Touch Smart)They put an external sensor on the users' fingers to control the pressure on the screen. In conclusion, they suggested that pressure based gestures have the potential to be used as an alternative input over multi-touch gestures. However, the study is more about usability than Accessibility. The research did not show the accessibility feature achieved by pressure based gestures. In my research, I want to evaluate the both accessibility and usability aspects of pressure based gestures. I will also try to evaluate more gestures like the pinch-to-zoom, pinch-to-rotate gesture with pressure based interaction.

The aim of the universal design is to make solutions for all, but in some instances, few people need extraordinary features to interact systems where universal design is compromised. We have developed some scenarios which show how users can benefit from applying universal design principles on touch gestures in a mobile application.

In a usability evaluation study of touch screens conduct by (Gao & Sun, 2015), some issue arises which can create problems for people above the age of forty while performing clicking, dragging, zooming and rotating gestures. They perform a usability test while performing a task in an inclined and declined position. Their studies show older users have more tendencies to make errors on touch screens while performing a task due to a relative lack of motor skills compared to younger people. The aim of the usability test is to find the fastest way of performing the task. It is evident that usability for small screens is relatively lower than the big screens for older adults.

Accessibility is considered very expensive, and hard to achieve for novice developers, and it takes time and research to understand how easily simple and easy-to-deploy techniques can provide accessibility. In this solution, we are utilizing the built-in functionality of the force touched gesture for interactive usage for older adults.

Accessibility is considered tough and hard to achieve for novice developers, and it takes time and research to understand how easily simple and easy-to-deploy techniques can provide accessibility. In this solution, we are utilizing the built-in functionality of the force touched gesture for interactive usage for older adults.

It is entirely necessary for Mobile Application Developers to make solutions which provide equal opportunities for a diverse group of potential users. User individual abilities vary widely, especially when considering older adults. They can have a vision, physical, and cognitive impairments depending on age. If developers consider this before developing solutions, they can also cover older adults' needs.

1.7 Goals and Purposes

The purpose of this thesis is to provide an alternative gesture for touch screen interactions with Universal Design Principle. The interaction methods should meet the guideline of Web Content Accessibility Guideline (WCAG), Web accessibility in mind webaim. and World Wide Web(W3C) Consortium so that designer and developers can make mobile interactions usable for everyone, and easy to learn without assistive technology (ATs). However, the universal design principles suggest that designer and developers design interface without special needs like assistive technology (Fadel, Kuntz, Ulbricht, and Batista (2016). However, every interaction should be fully functional with ATs for example screen readers and screen magnifier. To answer these questions, the following goals must be accomplished first.

- Study touch-based user interfaces, specifically force touch interaction in depth.
- Past studies on Elderly Friendly Design
- Evaluation of the force touch applications that are already developed.
- Designing the prototype with Universal Design principles and guidelines.
- The evaluation of prototype with iterative design principles.

The purpose of this project is to develop a method of interaction for force touch gesture also know as Touch Pressure. In the study (Shizuki, 2016) the define that new touch screen technology have touch controller with pressure sensitivity sensor. These sensors have a capability to sense amount of pressure or force applied to the touch screen. These new emerging technologies allowing users to interact with force touch with touch screens. Our goal is to find major challenges faced by older adults to use these gestures by interacting mobile devices. Because it is a new way of interaction in Mobile Computing. According to Universal Design Principles, the mobile gesture should be design in that way; the user can easily learn, memorize and discover gesture easily.

Research Questions

To reach this goal, we need to answer the following research questions:

1. What are the best tasks for the use of force gestures?

2. Does applying gestures on a touch screen enable older adults to perform force gesture more accurately than multi-touch gestures?

3. Do force based gestures make the tasks easier than multi-touch gestures?

4. Which gestures will older adults consider as alternatives to multi-touch?

To answer these questions, we have to conduct an in-depth study about force touch gestures and conduct empirical research which will include descriptive and exploratory studies of user behavior when applying force to a touch screen to complete a task.

1.8 S.M.A.R.T. Goals

1. Specific The goal is to make universal design force touch gestures on the IOS platform, which can make interaction on touch screens easier than traditional gestures.

2. Measurable After developing this kind of gesture, I have to evaluate gestures according to seven universal design principles. I need participants for an experiment to test that my gestures overcome their demands.

3. Achievable, The new iPhone 6S has a built-in sensor in the screen to sense the amount of pressure. IOS development kit allows developers to take advantage of (3D-Touch, 2016) to design new gesture on IOS Platform.

4. Relevant This is a new area of research for touch screen accessibility evaluation. With proper calibration, it should be possible to use pressure based gestures as an alternative method of input on mobile devices.

5. Time-bound To create different gestures as an alternative input method also requires an evaluation of traditional gestures. This necessitates a literature review from the past studies. Then, new gestures will be developed with according to universal design principles.

Force touch senses the amount of pressure applied on the touch screen. It can detect multi-touch gestures, like one, two, or three finger touches to the screen simultaneously (Shizuki, 2016), along with the relative pressure from each finger on the screen.

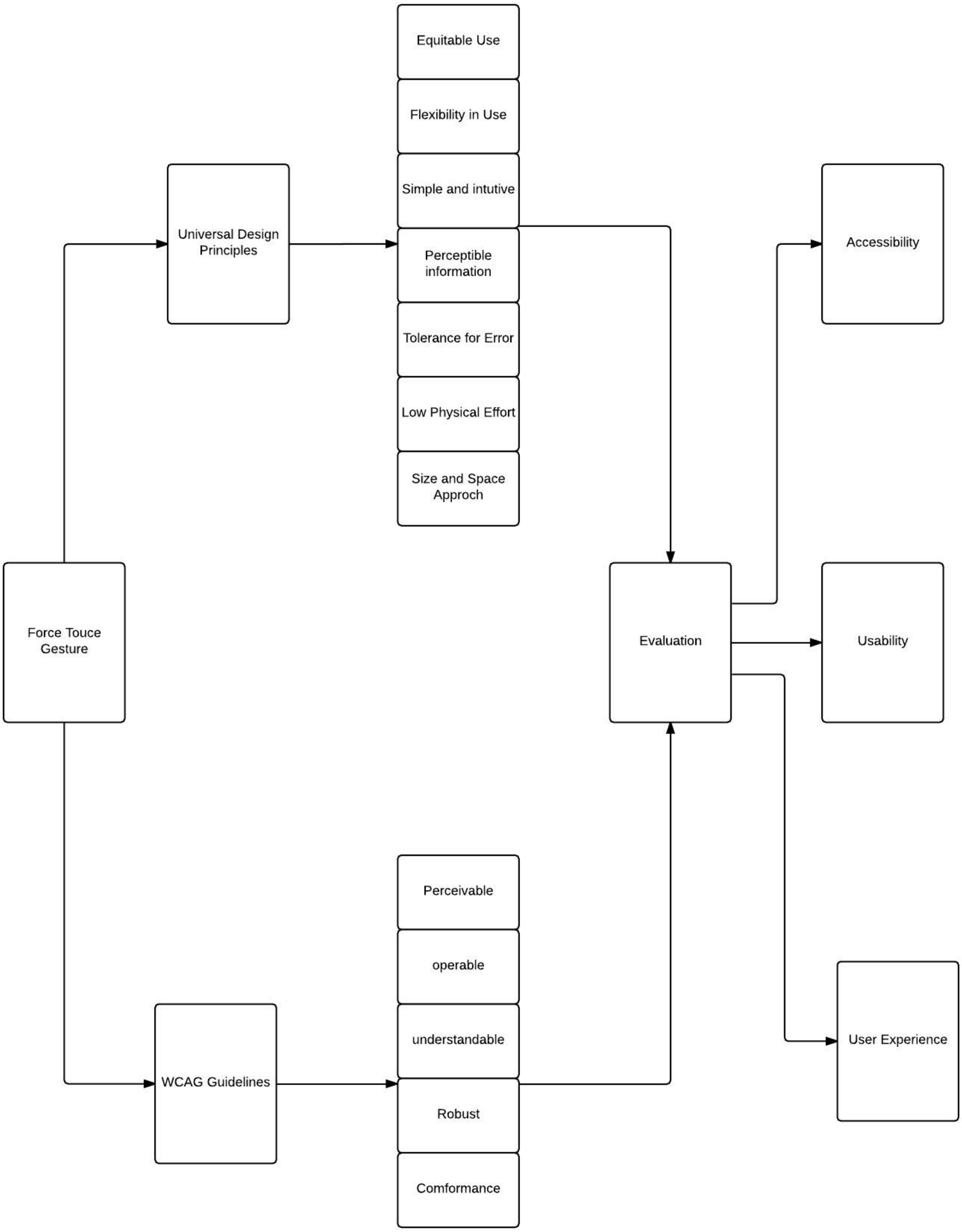


Figure 1 Gesture Evaluation

1.9 Research gaps

This study aims to fill the gaps in force based touch interactions. This force touch gesture probing study will be based on new accessibility principles and guidelines. The previous studies evaluate the user interaction with everyday touch screen interaction like multi-touch gestures with WCAG 2.0 guidelines. The force touch gesture also is known as (3D-Touch) introduce in 2016 it is observed that touch screen in mobile device senses the amount of pressure from the fingers. This new interaction paradigm opens new gates for researcher and practitioner in human-computer-interaction to work on new ideas for making mobile interaction more accessible and usable for users.

Past studies show that force-based touch interactions have been done with wearable equipment. In new IOS devices, the screens have the capability to sense the amount of pressure applied to the screen. Previous studies have suggested that force is more natural as compared to traditional touch-based user interfaces.

The literature review shows that force based gesture interfaces have not yet been addressed properly. Although more researchers are attracted to this new type of input gestures, especially force-input interfaces, this area still has not been investigated enough. Kobayashi et al. (2016) Did an experiment, and their research shows that force touch gestures can improve accuracy and efficiency by providing visual, auditory and visual-auditory feedback on the gesture control. However, their experiment was based on young people with different hardware. The past studies show that there is a gap between the implementation of guidelines and the actual practice in mobile application development. This challenge needs to be addressed with proper theoretical and practical approaches found in the literature review implementation section.

Another gap in force-touch type gestures arises since past studies cannot address a valid new research question in a qualitative way, particularly regarding user experiences in emotional and social aspects. Touch-based interaction methods should be evaluated considering potential user feelings about a new model of interaction, particularly elderly users who have lower mental and physical power as compared to young users. Past studies made improvements on non-sight and non-visual interactions, but they failed to address the question of physical and cognitive loads on the older adults while interacting with pressure based gesture tasks.

1.10 Research Aim

- A literature review concerning touch screen usability.
- A literature review concerning touch screen accessibility features.
- A literature review concerning accessibility and usability features guidelines by WCAG and Universal Design Principles.
- A literature review concerning pressure based gestures and their applications for touch devices.
- A literature review of guidelines about mobile accessibility.
- Evaluation of pressure based gestures in any application with a usability aspect.
- Designing a prototype for universally designed mobile applications for pressure touch gesture interactions.
- Development of pressure touch guidelines for mobile devices with universal design.

1.11 Definition of Key Terms

This thesis concerns the challenges presented in touchscreen accessibility for the elderly. In this section, We showcased the relevant investigation has been done in the field of Force Gesture Based Touchscreen interaction. The performance of older people's touch interaction was evaluated with force touch gesture as an alternative to multi-touch gestures like pinch, zoom, and sliders. Unlike past studies that tried to compare force or pressure effects on the touch screen by external or wearable equipment, this study addressed the potential importance and effectiveness of force gestures built on the principles of Universal Design.

Table 2 Definition of Key Terms

Terms	**Abbreviation**
UD	Universal Design
HCI	Human Computer Interface
HCD	Human Centred Design
UI	User Interface
3D Touch	Three-Dimensional Gesture
W3C	The World Wide Web Consortium

Terms	Abbreviation
UD	Universal Design
WCAG	Web Content Accessibility Guidelines
WAI	Web Accessibility Initiative
HCD	Human Computer Design
IP	Internet Protocol
UN	United Nation
UNCRPD	UN Convention on the rights of persons with disabilities
TBA	Technology Based Accessibility
ICT	Information and Communication Technology
AT's	Assistive Technology
PWD	Person with Disabilities
EU	European Union
BBC	
NUI	Natural User Interface
ISO	
API	Application Programming Interface
SDK	System Development Kit
UX	User Experience Designer
OS	Operating System
IOS	Apple Operating System
NSD	Norwegian Centre of Research Data
HiOA	Oslo and Akershus University College

1.12 Time Plan

The figure below divides the whole research process into three phases, and the task mentioned in the each phase should be considered a milestone. The detailed timeline with a task summary has to be given in a Gantt chart, which shows processes and deadlines. A literature review was a part of the first phase of this thesis. During this process, in-depth studies of touch screen behavior were performed. Phase one tried to review the latest research approaches have been used in the field of human-computer interaction, and provide a solid background for further investigations. The literature review element was based on peer-reviewed journal articles in the field of HCI. The action research, which is defined in the methodology section in detail, has been divided into three phases: plan, act and observe and analysis. These three phases have been helpful to understand the practice of principles of UD(Universal Design) and WCAG Guidelines about accessible force touch gestures for mobile interfaces.

In the following section, we have described the timeline of this research in three phases of action research. This model should help analyze the hypothesis questions, which are based on evaluating and developing three-dimensional touch gestures with universal design principles and user stories.

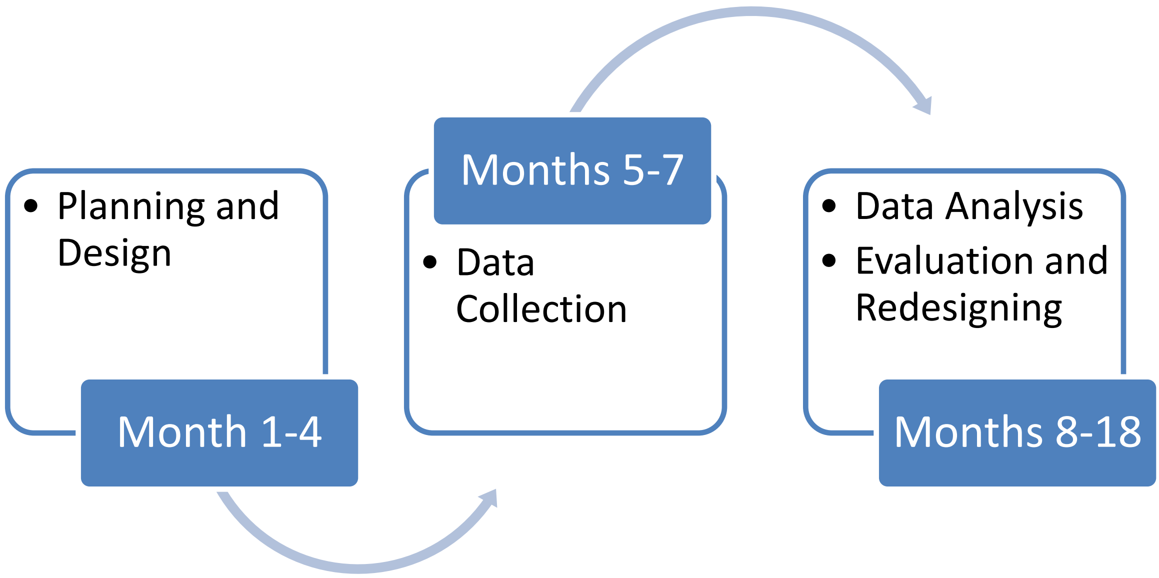


Figure 2 Timeline for the Master Project

The second phase includes data collection and prototype development. The phase one studies the research problem, including an in-depth study of the relevant areas and an observation of pre-existing solutions in other similar applications to help develop the best possible prototypes.

1.13 Gantt charts

The Gantt Chart has been divided into two parts. Figure 3 Gantt chart from for Phase 1 described the detailed tasks that have been done in this phase. Figure 4 Gantt chart Phase 2 and 3 describe the main task that have be done.

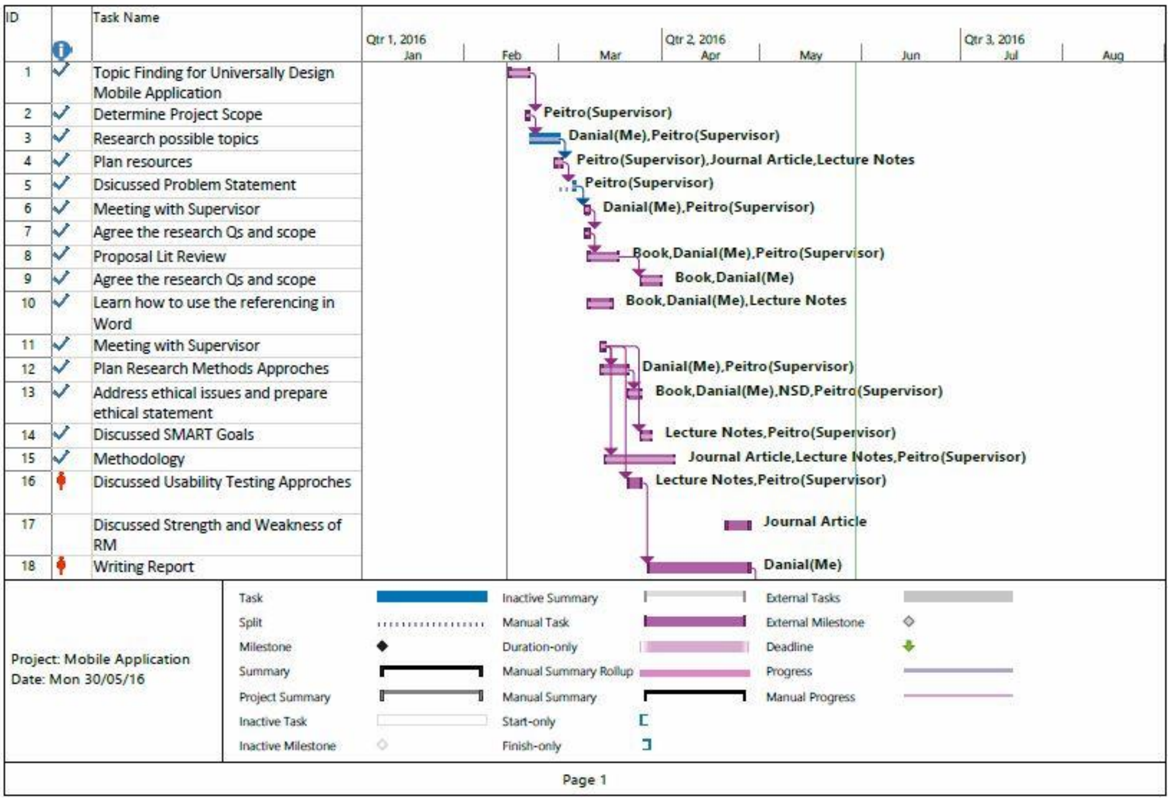


Figure 3 Gantt chart from for Phase 1

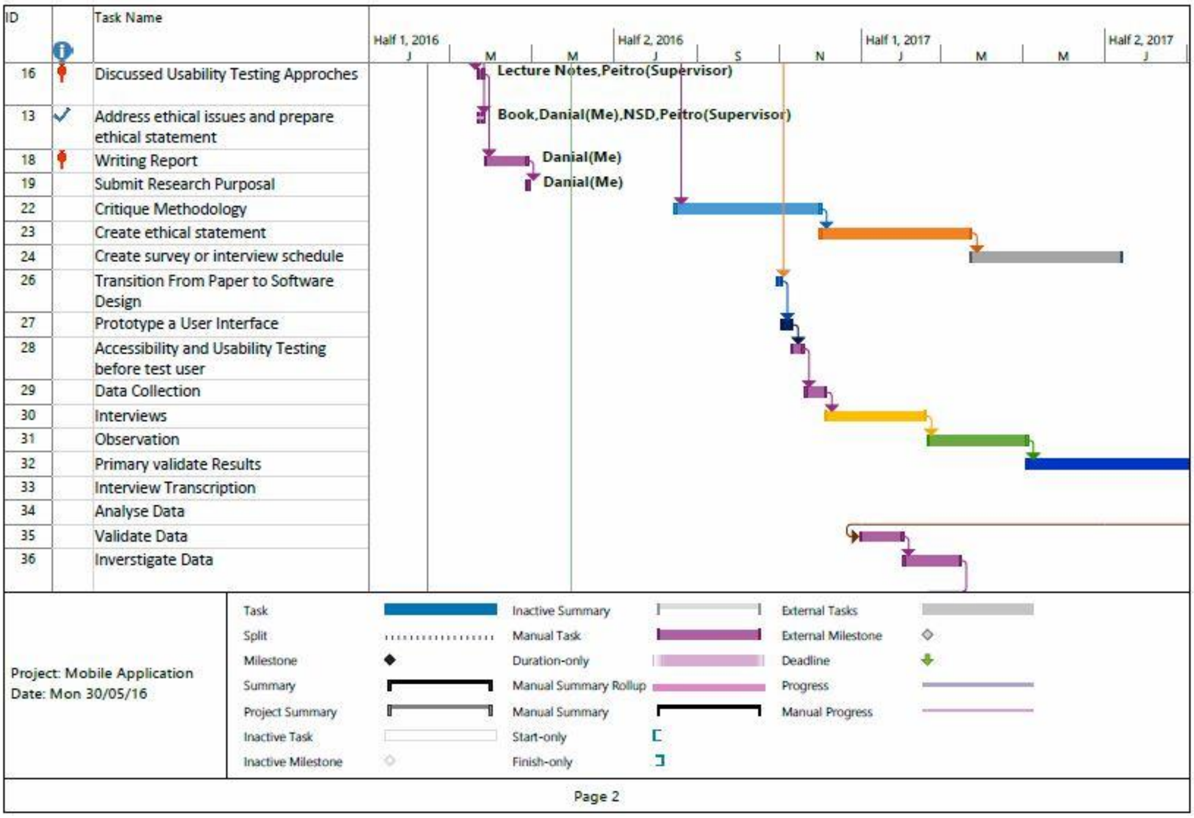


Figure 4 Gantt chart Phase 2 and 3

This preliminary work plan for the whole research project will be conducted in this Masters Thesis on universal design, pressure based mobile applications.

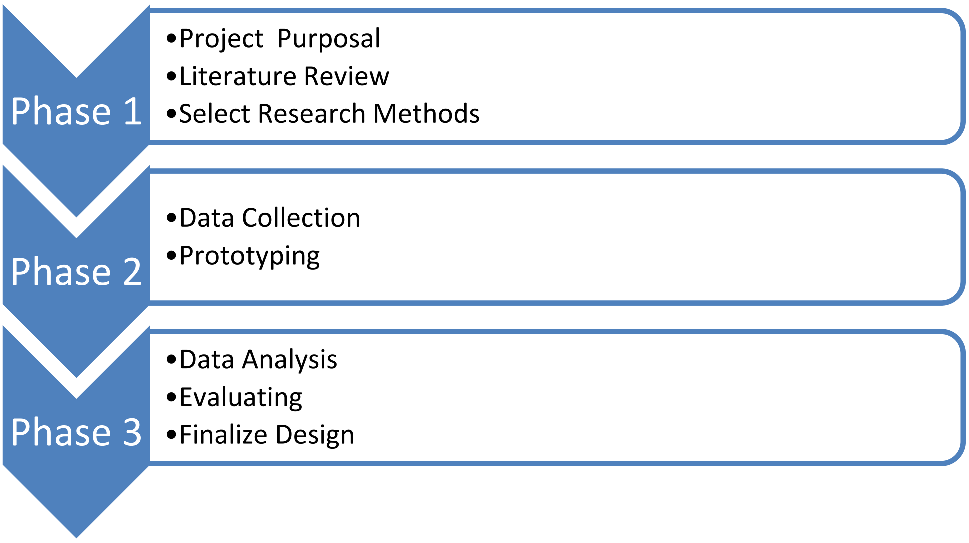


Figure 5 Time Plan

1.14 Chapter Summary

This chapter has laid the overview of this study. This chapter help to understand the basic purpose of this study and research problems and our purposed plan. We have presented the basic definition of terms so the reader can easily understand the abbreviation we used in next chapter. The next chapter will about the background of accessibility Principles, Guidelines, Laws, and legislation which every accessibility enthusiast should follow to develop solutions for accessible ICT products.

Background

2.1 Inclusive Design and Approaches

“Inclusion is a broader approach and involves removing barriers so that individuals with a disability can live and participate in regular society. Accessibility is one way to achieve this goal”.

The design for All does not mean that it is just passing the grade on usability test. In the design, the framework defines by Richardson (2011) they mentioned that all functionalities in the ICT system are meaningless if the system is inaccessible to any user for any reason.

Inclusive design means that ICT solutions can be designed in this manner so everyone can have access to systems, devices, or interfaces without any assistive technology or special designs. The device and platform we are evaluating is Apple, which follows inclusive design principles, and is considered a pioneer for accessibility in the market Xu, Cornelio, and Gianfortune (2016). They have designed “Siri” for Apple devices so many users including the blind, motor impaired, elderly can talk to their devices rather than use physical gestures. However, according to our observations, we have determined that Apple has focused more on blind users than older adults. This is the main reason to evaluate and redesign force touch-based gestures for older adults. Mobile interfaces for older adults need to be usable, engaging, easy to use, meaningful and motivate the adoption of technology. However, current mobile technologies do not meet the needs, experiences, and have limitations of older adults, and have many accessibility problems.

2.2 Universal Design

There are seven principles of universal design which were developed in 1997 with the aim to provide equality for everyone when developing anything from design engineering to the human-computer interface(Story, 1998). The seven principle are as follow.

Table 3 Universal Design Principles

1. Equitable use
2. Flexibility in use
3. Simple and intuitive

1. Equitable use
4. Perceptible information
5. Tolerance for error
6. Low physical effort
7. Size and space for approach and use

This study aims to find a relationship between Universal Design and accessibility to verify Universal Design principle in a force touch gesture, before that we have to find a specific definition of Universal Design for the user interface. Universal Design is a broad term; the idea was borrowed from making Building and Environment accessible for disabled people(Story, 1998). Later, it was implemented in other fields especially in information technologies to design ICT system accessible for the greatest number of the user, to the largest extent possible, without any specific design.

Universal design means to design for all. It means that it can provide equal opportunities for everyone to use systems without barriers. However, the essence of Universal Design is that it always encourages developers and designers to help develop new technologies to help people with disabilities and overcome their hurdles. New devices with emerging technologies are coming out on a regular basis, so we as researchers need to understand what new features these technologies offer to the user. Are they fulfill user requirement and expectation it needs to test, evaluate with Universal Design Principles.

Different researchers in various studies expand Universal Design principles with a set of guidelines. Like in the study of evaluating online courses with Universal Design Principles Fadel et al. (2016) they divided each principle into four guidelines and evaluated each guideline with the user interface they have designed for users. We had expanded this principle into four guidelines and defined our details findings which guidelines these force touch gesture we have observed and not observed in the experiment and which guidelines was not suitable for this study. These are the following feature we try to simulate in our prototype with Wizard-of-Oz setup.

2.2.1 Principle 1: Equitable Use

The pressure based application will create alternative interaction methods. This will help motor impaired people to use one hand or single finger to perform force-to-zoom or force to rotate gesture.

2.2.2 Principle 2: Flexibility in Use

This principle helps users to interact with touch screens in an exceptional condition, like sleeping, walking, jogging or while driving or riding. Sometimes users hands or fingers are occupied with a various task, so pressure based gesture will help them to perform with a single hand or a single figure.

2.2.3 Principle 3: Simple and Intuitive Use

Multi-Touch gestures are very complex for different users, like older adults, who may have problems pinching the screen to zoom in and zoom out. Pressure based applications make this simple by using pressing sensitivity. The haptic touch or taptic feedback help the user to navigate screen elements like physical keys.

2.2.4 Principle 4: Perceptible Information

The performance of older adults users was affected by the motor and visual disabilities. It has been observed that this kind of user group may find touch interaction tough. This principle helps them to perform tasks in alternative ways.

The two big platforms, Apple and Android, have accessibility features for impaired people, but the difference is that they both have different gestures for the same task, which creates obstacles for users, like the user who used ATs.

2.2.5 Principle 5: Tolerance for Error

Sometimes unconscious touch creates an unwanted task. The universal design gesture helps to reduce errors by implementing pressure on important tasks like submitting and payments. These gestures can help users to recognize necessary actions which assist them in preventing false payments.

2.2.6 Principle 6: Low Physical Effort

This principle minimizes physical efforts by interacting with the application with a single finger and single hands. This principle helps people use mobile applications with different orientations by performing a small amount of pressure on the screen.

2.2.7 Principle 7: Size and Space for Approach and Use

Sometimes children's who have little fingers face the problem when interacting with big screens, like Phablet which has a display size of tablet computer but with mobile functionalities. Pressure based gestures try to help the users interact easily on big screens as well by making interactions more natural.

2.3 Theoretical Models of Disabilities

There is six theoretical model define by Bohman who are currently working on the draft on the international association of accessibility profession mention benefits and weakness with examples. The observation found that these model helps to generate a theoretical model of Aging. The literature review shows that there in no specific theory available which identified an age-related issue in human-computer interaction domain. The theoretical models of disabilities are followed.

- Medical model
- Social model
- Economical model
- Functional model
- Social and cultural model
- Charity model

These models help us to get deep knowledge about the older adults preferences in the emerging technologies like force touch. After gaining the insight knowledge about theoretical models, this study can play it role to generate the theoretical model of aging in future. These models help researcher and designer to understand of which model align most closely with Universal Design and accessibility principles.

2.3.1 The Disability Gap Model

Oviatt (2003) define that disability gap model derives from the social model of disability. From the literature, we have found many examples where demands of the society make people disabled. Like emerging technologies create a barrier for older adults because of lack of knowledge with new design and features. The Department of Assistive (TECHNOLOGY) in Norway defined disability gap model.

"A disability is a discrepancy between the capabilities of the individual and the functional demands of his/her environment in areas which are significant for the establishment of independence and a social life."

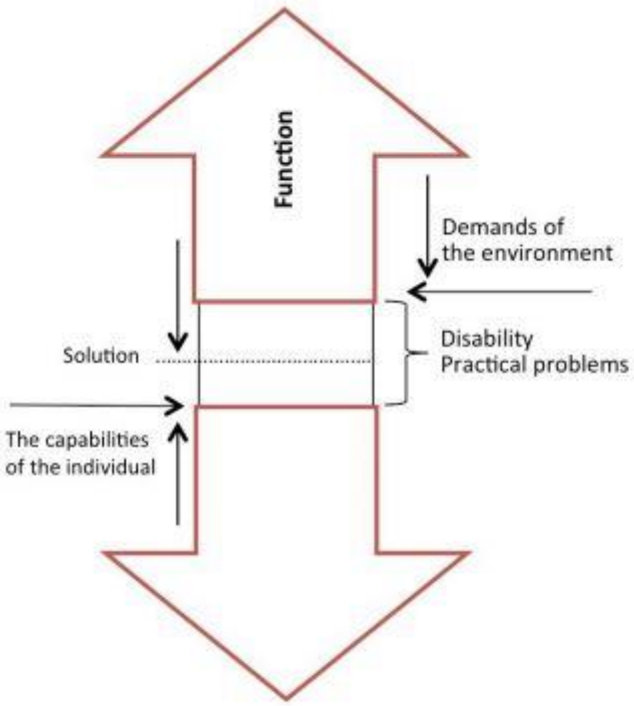


Figure 6 The relationship between the capabilities of the individual and the Environment (TECHNOLOGY, 1990)

2.4 Human rights and disability

The UN (UnitedNations) on the rights of persons with disabilities (UPCRPD) has focused on accessibility and technology. Today, new technologies provide users new ways of interaction to reduce the barriers for people with disabilities.Bühler (2016) defines the new UN (CPRD) goals to make the lives of individuals with disabilities better through policy for technology based accessibility. The year 2016 was the 10th anniversary of the adoption of the Convention on the Rights of Persons with Disabilities (Development, 2016). According to the UN (CRPD), in the past decade, policy maker brought significant changes in the life of individuals with disabilities through a new combination and implementation of technology-based support for PWD(Person with Disabilities).

2.5 Agreements and Laws

2.5.1 Legislation

The Norwegian government had written about their vision for people with disabilities to ensure that everyone has equal right and opportunities to participate every field of life. The act Know as "Norwegian Anti-Discrimination Law" published by (Sosialdepartementet) this is the first law about prohibition based on ethnicity and religion etc and act came into force on 1 January 2006. However, Norwegian Government works ICT discrimination law as well to provide equal access to ICT services like Website, Mobile Application, and Tickets Vending Machine follows the "Anti-Discrimination and Accessibility Act." The Norwegian Government is working collaboratively with EU(European Union) and organization which aims to increase accessibility in every field of life.

2.6 Standards and Guidelines

The World Wide Web Consortium (W3C) is an international community where member organizations, a full-time staff, and public work together to develop web standards. This community is currently working on two drafts which are related to current emerging technologies introduce lately. Both WCAG 2.1 and Mobile Accessibility Guidelines are in (W3C) the working draft and open for public comments. However, the WCAG 2.1 Guidelines are published with fine-tuning and on a new principle, as compared to WCAG 2.0. The new principle is about conformance. The new WCAG guidelines have improved methods of accessibility testing, including for users with low vision, users with cognitive and learning disabilities, as well as accessibility criteria for Mobile Devices (Intopia). The new WCAG 2.1 Guidelines have 28 new success criteria.

2.6.1 WCAG 2.0 to WCAG 2.1

The Web Content Accessibility Guideline by (W3C) has drafted a best practice guideline for mobile interface designs. This working group charter is continuously developing accessibility guidelines for new and advanced technologies, also known as enabling technologies in ICT. The first WCAG 1.0 draft was created by W3C/WAI(Web Accessibility Initiative) in 1999 which, for the first time explained how to make web content accessible to PWD. The WCAG 2.0 version was published in 2008 (W3C) it has four principles (perceivable, operable, understandable and robust) which are subdivided into 12 guidelines. The WCAG 2.1 working draft version introduce in 2017. It was comprehensively revised compare to WCAG 2.0. This working draft brings new 28 new success criteria including methods of automatic, semi-automatic and manual testing of mobile and web applications.

In the User behavior analysis phase we focused on three areas of disabilities: Vision, Motor, cognitive load. The WCAG 2.1 initiative provided the guidelines for developing mobile interfaces based on mobile accessibility guidelines. According to WCAG 2.1 (W3C), the ICT system must follow five principles.

- Perceivable
- Operable
- Understandable
- Robust
- Conformance

These principles apply to new emerging technologies as well. However, the WCAG 2.0 guidelines do not cover the new technologies on the market right now, such as virtual reality, wearable devices and smart interaction methods in the user interface. We have not found any proper guidelines for (3D-Touch), force touch or pressure touch in WCAG 2.0. That is why we have to look into WCAG 2.1 guidelines.

This new guideline has more impact on our research because we used an Apple iPhone for evaluating and designing force touch gesture which was just released one year before this draft was made public on the W3C website. The WCAG 2.1 was sorely needed, and it includes guidelines for mobile user interface designers of new technologies, like force touch and three-dimensional touch, which are used in new touchscreen mobile devices.

Some examples of the new success criteria include in WCAG 2.1 focusing on three key area as follow (Intopia):

- Users with low visions
- User with Cognitive or learning disability
- Accessibility of mobile devices

The WCAG 2.1 include all previous guidelines from WCAG 2.0 but as we mention before this working draft focusing on new technologies it helps us to test force touch gesture with these guidelines as well. According to the new success criteria, we can test force touch gesture with a screen reader and other assistive technologies. These gestures are new for everyone including user with disabilities. For instance, it is observed that these gestures are not discoverable for the blind user due to lack of knowledge. According to WCAG 2.1 principle "understandable " guideline 4.6, every new gesture in the mobile interface will have the clear instruction of use. The instruction should have in the form of overlays, tooltips or tutorial form. We have observed that vendor of (3D-Touch) did not provide any instruction on the website, user manual or in mobile.

This new guideline gave us a new testing procedure for gesture interaction with Assistive Technology. These guidelines provide new functional testing methods for accessibility testing auditors to evaluate new technologies with revised guidelines of WCAG 2.1 Wille, Wille, and Dumke (2016). As a result of this testing procedure, it generates numerical value about the degree of accessibility. In our finding, we will able to analysis how well these gestures meets the success criteria, for example, each success criteria associated with levels of conformance: A(Lowest), AA, and AAA (Highest).

The World Wide Web Consortium (W3C) has defined guidelines for mobile accessibility, but they are in working draft form now. Under the supervision of Mobile Accessibility Task Force, it has four principles: perceivable, operable, understandable and robust. These principles have defined "how touch gesture operated?" which aims to make gestures easy to use. It has defined how gestures work with assistive technology. Users can create custom gestures, but they should be memorable. Effective gestures for any user group should be effectively learned and remembered and less effortful. It is also mentioned that user manuals for using these gestures should always be available when users need them.

The WAI works with organizations from all over the world, like (BBC) and (Funka), especially concerning mobile accessibility guidelines. The aim of this joint research is to develop guidelines and techniques to make mobile interactions more accessible and usable for full user groups. The WAI define (Accessibility) as follow: “Accessibility intends that people with disabilities can perceive, understand, navigate, and interact with the ICT system, Accessibility also benefits others, including older people with changing abilities due to aging.”

The (W3C) goals and directives available are to help researchers and developers to develop mobile applications and interaction with universal design principles with usability and accessibility in mind. From the literature study, in a study Abascal, Azevedo, and Cook (2016) evident that developers and designers cannot understand the guidelines and principles properly or they are ignorant. The firms are now hiring accessibility experts who evaluate the accessibility principles and guidance in any product of system to aware designer and developer for accessibility violations.

Some of the guidelines specified in WCAG can lead to improved Accessibility in our force touch gestures. For example:

WCAG 2.1 advise designers to address challenges by providing alternative ways of performing the same task. This can help people who have motor impairments or people who are in exceptional conditions like weather, noise or busy environments to use multi-touch tasks with head pointers or stylus.

Placing buttons where they are easy to access recommended that designers and developers keep in mind ease of use of interaction for the motor impaired, as well as people who only have one hand available to perform a task. This WCAG guideline suggests that an easy-to-use button placement helps these kinds of circumstances. In our recommended interaction methods, we will provide force-touch based gesture with buttons for various tasks like force-to-zoom and force-to-rotate.

Accessibility and usability in touch screen mobile applications can be evaluated by experts because there is no way to check the accessibility of mobile applications via automated testing tools. Now, open source platforms like (Google) working accessibility scanner that can help developers and designers to quickly scan accessibility issues from the interface in any application installed on the Android operating system.

3 Literature Review

3.1 Chapter Overview

In this chapter, I have reviewed the relevant literature to this study. First, we have to define what the techniques we have applied on the literature review to find relevant results which related to this study

The preliminary research on the elderly friendly user interfaces in the first phase of this project gathered lots of data on interaction paradigms for elderly populations. We used Nvivo software to generate some analysis to identify other focus areas and make this research more rigorous and trustworthy. We have generated a word tree from the literature.

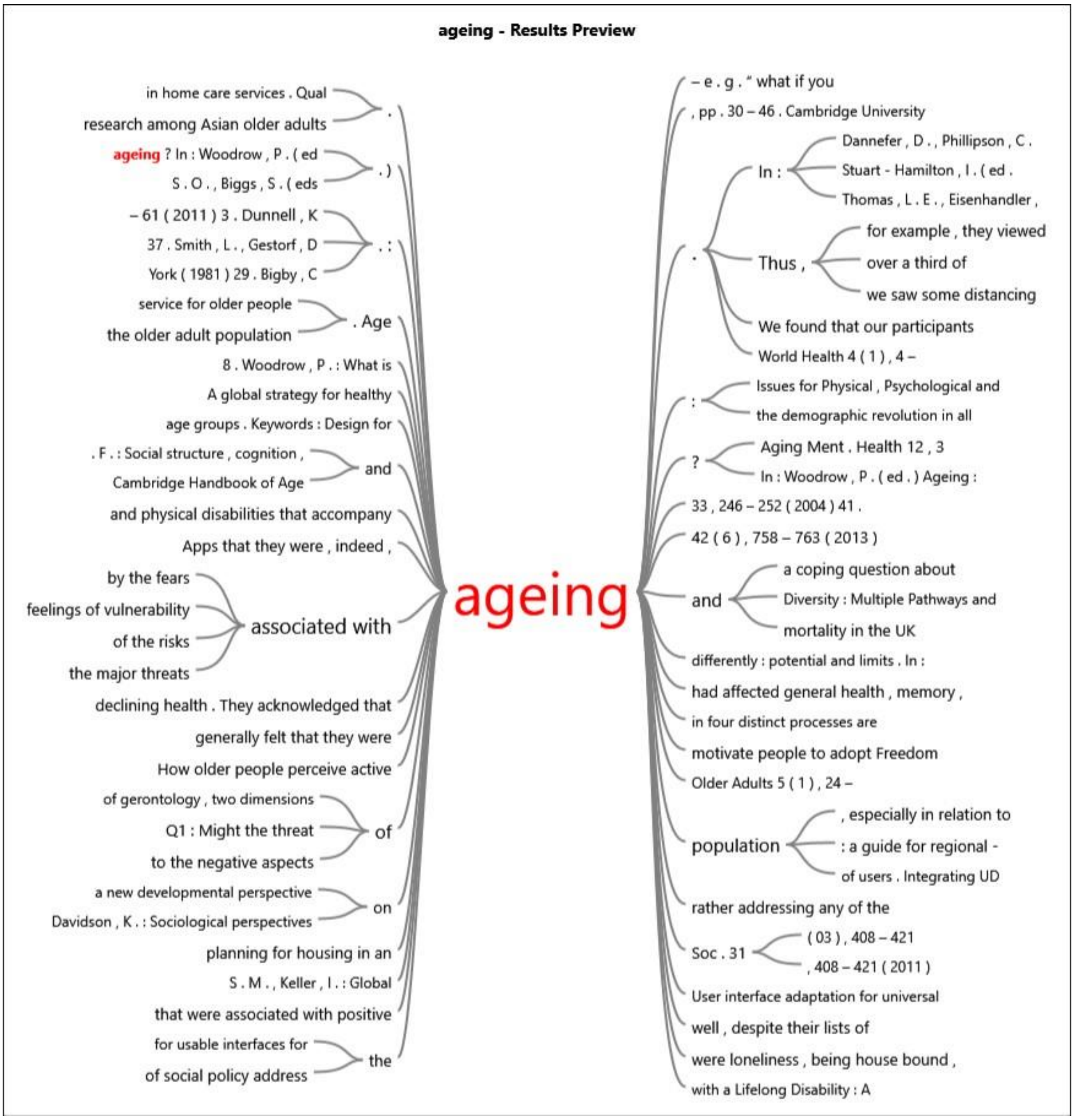


Figure 7 Word Tree for functionalities related to Ageing from literature review

The below literature review was produced to gather recommendations and reviews on techniques and guidelines for user experience with touch-based interactions, in particular for those with pressure properties in context with Universal Design Principles. To accomplish this, we have done a systematic review of research with the help of a qualitative analysis of the selected papers with Nvivo software.

3.2 Systematic review

The objective of this thesis is to design and evaluate a force touch gesture. We need to identify force touch gesture techniques which are accessible for older adults. This project has three phases. We divided our literature review into three categories to achieve our objective and applied a systematic review of elderly friendly designs following the model purposed by Wohlin and Prikladnicki (2013), which helped us to find relevant literature for our research, and was aided by a snowballing search strategy. It helped us to identify necessary libraries to find past papers from the leading journals and learn how to find those papers quickly and with suitable keywords. In the first phase of this thesis, we identified our search criteria for relevant literature review with sufficiently high quality.

Literature searches were conducted in the various digital library like (HIOA, ACM, IEEE, Springer and Google Scholar using the following keywords and strings suitable for each search engine: "Elderly In a Friendly way," "Natural User Interface," "Interact 3d". The results were put into the inclusion and exclusion criteria. The inclusion criteria were:

- The paper is available for reading in the selected database
- Should have Universal Design, Inclusive design, Design for All,
- Discuss design methods for Elderly people
- Must have experiments and results showing achievement
- Qualitative Data Analysis with user Experienced design

The exclusion criteria were:

- Only have quantitative data
- Only discuss the three-dimensional interaction techniques, not design for all

These strategies helped us to include only valid information for the aim of this research. We have discarded many papers. One example was a paper concerning design for older adults. It did not include a methodology that was defined with for Universal Design principles. Because the three-dimensional gesture was evaluated and designed for not only older adults, it can be universally accessible for everyone.

We literature study found the papers from all over the world, but our focused was on "Ageing," so we have included finding from the countries which have an aging population more than rest of the world. As the study of Kocatepe, Ozguven, Ozel, Horner, and Moses (2016) reflects on the aging of the baby boom generation people who expected to be over the age 65 in the next two decades. We have found studies from aging population countries like Western Europe countries, Singapore, Japan and the United States because these countries were affected by a baby boom after a world war and then an improved standard of living. Additionally, these populations have better education levels and have good ICT literacy as compared to rest of the world which is helpful, because we need older adults, who have experienced internet users within what is considered a digitally young generation.

The first part of this research is an empirical study. These empirical studies were conducted on recent work with mobile user interfaces for older adults, or on Elderly friendly user interfaces. Mobile interface design is not new. Researchers have been working with it for last two decades. However, designing a user interface for mobile devices with Universal Design principles still needs much work. Researchers are investigating the different accessibility issues faced by older adults while using mobile devices, but there is no up to make the designs which been purposed in the context of touch screen gestures. A literature review reveals far too many examples of touch gesture usability and accessibility issues among older adults.

In a peer-review conference article titled "Design for Ageing" by (Chêne, Pillot, & Bobillier Chaumon, 2016) highlights accessibility issues faced by elderly people using tactile interaction. This article further suggests that seniors make mistakes on touch screen interfaces due to shaky hands, lack of finger sensitivity, low pointing-capacities or finger electrical conductivity, visual impairment, and audio disabilities. This article also defines why some more frequently used gestures like "tap," which is considered the basic gesture on touch screens, is not easy to perform for elderly people. This gesture, among others, requires more certain cognitive, motor and visual abilities, which are commonly affected by minor or major disabilities in the elderly population Liu, Chang, Wang, and Lai (2016). This research helps us to understand user requirements for tactile feedback interaction. Since 3D-touch has tactile feedback, this research can help us design force gestures with the needs of older adults in mind. The author also highlights that older adults find difficulties with interact with tactile interaction. Furthermore, they define the optimized tactile interface for novice elderly population which helps to reduce cognitive load from the user.

Tactile feedback has functionalities to provide real button interaction on the touch screen. It is necessary for elderly friendly designs because this targeted group likes mobile devices with physical buttons Chung, Kim, Na, and Lee (2010). The real button has the capability of giving the user feedback about pressure and abutment. The author also defined an optimized solution by designing a tactile mobile interface including “Design for All” principles, which is also our aim with this research. The comparative test between tactile user interfaces vs. classical touch interactions shows that this solution reduced mistakes by older adults in different tasks. For example, in one experiment the researchers Chêne et al. (2016) compared single-handed vs. two-handed interactions where tactile based interactions were used as an alternative for two-hand gestures, considering the common practice of older adults to try to use their mobile with both hands. In another user test, they evaluated multi-finger usability testing with thumb-based gestures, and they found that the large screens trend in this era creates limitations for thumb-based gestures because of the presence of unreachable regions, like in vertical vs. horizontal gestures. The researchers divided the screen into 12 regions and tested with older adults.

As for the results of these papers, which are listed below, we found some useful recommendations about how to make touch screen gestures accessible for seniors. This consideration addresses the most common accessibility and usability issue that older people encounter while interacting with the *interface*. To study user stories from the different papers, we will able to evaluate and design user-centered designed touch gesture for older adults. User stories can be found in the aging section and documented as accessibility and usability stories.

Most previous studies on force touch interactions concerned wearable equipment. The aim is not to design a new gesture for the mobile based application. The idea is to develop and evaluate the previous gesture according to universal design principles with a fresh perspective. (Bhuiyan & Picking, 2011) illustrate their information on the types of gestures which show that gesture-based technology was expensive because it is required that the user wears special gloves on their hands, where microcontrollers were used to detects the motion by wire.

Literature studies found lots of obstacles in the way of the touch screen users, for various reasons. This study hopes to help users reduce possible mental and physical loads while using the gesture-based interfaces. The findings of this thesis can help researchers who are interested in developing universal design gestures for the touch screen to become aware of how to use force touch as an alternative to some traditional gestures. Moreover, it can help them to understand potential problems that can occur when the human finger applies pressure to the screen, and how to address the issue properly.

Table 4 Past Studies on Gesture Design for Elderly People

Factors	Description	Researchers
Functionalities	Usability evaluation of numeric entry tasks on keypad type and age	(Kim & Jo, 2015)
Flexibility	Control with hand Gesture with Elderly people	(Liang & Lee, 2016)
Usability	How easy to remember what to do when to do	(Gao & Sun, 2015)
Login-ability	older adults using freehand gestures	(Bobeth, Schmehl, Kruijff, Deutsch, & Tscheligi, 2012)
Functionality	How easy it to use the experienced once it learned	(Findlater et al., 2013)
learnability	Intuitive learnability of touch gestures for technology-naïve older adults	(Mihajlov, Law, & Springett, 2014)
Pressure	pressure sensing interactions with tactile feedback	(Rekimoto & Schwesig, 2006)

Additionally, I have read some articles on human-computer interactions as well as some specialist journals and conferences reports on aging, disabilities, and technology.

3.3 Human Centred Design

Human Centred Design (HCD) focused on the user needs. The new emerging technologies provide too many features to users, but some of the features are problematic for some users. In our case HCD is relevant to accessibility, usability, and user experience for force touch gestures for older adults. HCD helps to gain a real knowledge of the user. For our research, we have to understand the requirements of the older adults. Before developing any innovative interaction methods for any user group, it is very necessary to read the (ISO, 2016) guidelines thoroughly. In our case, the user is already using multi-touch gestures on their smartphone and is satisfied with these gestures. Introducing a new force-touch based gesture is very challenging when it comes to satisfying accessibility and usability requirements.

3.4 Natural User Interface for three-dimensional touch

The NUI (Natural User Interface) helps us to develop gestures and actions which are naturally designed for older adults(Wang, 2016). It helps us to design an Elderly Friendly Mobile environment which encourages older people to use screen devices in their daily life. In our scenarios, where older people feel pain or frustration while using the touch gesture, NUI helps overcome the barrier with this targeted group. The aim of this research is to study where force touch gestures play roles as alternative ways of interaction.

Suggestions and feedback help to create the fully functional universal design mobile application which can overcome accessibility issues for older adults in an effective and efficient way.

Previous studies show the weaknesses of usability testing. The validity and inspection of the usability testing cannot cover all usability issues, so we have to focus on a combination of frameworks which have different methods of testing. de Paula, Menezes, and Araújo (2014) recommend the involvement of user-centered design principles to overcome the weaknesses of usability testing by involving potential users in the fundamental process of designing the mobile applications.

The (W3C, 2016) have new definite requirements for enabling technologies for the design of new input methods like force touch or three-dimensional touch gestures. In this working draft, it is recommended that new properties of input like pressure or force touch gesture, will follow accessibility guidelines. According to W3C guidelines, touch events generated from three-dimensional touch gestures are used as an alternative input to perform touch events like touch start, touch move, touch end, and touch cancel to complete a task on the touch screen. The W3C (W3C, 2016) encouraged the developers of the touch gestures to keep users with disabilities in mind while using these gestures in Native or Web Application. The (W3C) guidelines about mobile interface strongly encourage developers to design gesture with accessibility in mind. According to (W3C) custom gesture can be a challenge to discover. This is the criteria we are going to consider in our experienced user design as well. It is necessary for vendors like Apple and Android to mention new features like 3D-touch in their quick start guide and information about how this new feature works. Unfortunately, we have not found any information about 3d-touch in Apple manual guide.

3.5 Evaluation Methods

There are three evaluation methods involved in the testing of force touch gestures. In the study Hosono, Inoue, Nakanishi, and Tomita (2016) use term “Well-Being” for user experienced. This study argued that User Experience is the broad term in which usability and accessibility are a sub-category of the User Experience.

- Usability
- Accessibility
- User Experienced

3.5.1 Accessibility Testing.

Accessibility aims to ensure the better quality of life to people (Findlater et al., 2013). The accessibility test the user interface with user needs to interact with the system in with limited functionalities(Sensory, Physical, Cognitive). There are two methods of accessibility testing automatic and manual also known as Heuristic Evaluation. There are many automated tools available for web accessibility testing(Abascal et al., 2016) but they are not sufficient, and it always needs to test system with a real user with Assistive Technologies like screen readers.In our study Heuristic Evaluation identifies critical issues emerging in mobile interface design. Accessibility test procedures for touch screen are not well documented. There is no authentic and detailed testing procedure found in the literature review. The WCAG 2.0 lacks knowledge about how gestures should be designed.

Accessibility refers to products, devices, and services for people with disabilities which ensure they can get and process information without limitations. Technologies are changing in seconds, but implementing accessibility in systems takes more time. In this era, developers have to focus on accessibility while developing solutions for the inclusion of people with disabilities. (Bühler, 2016) Purposed a new approach for the developer and designer, "Technology-Based Accessibility (TBA)" which contrast with the conventional approach to providing solutions to PWD, with assistive technology or appropriate solutions. The developer focused on accessibility from the initial stage of the projects.

For example It is observed that most of the multi-touch gestures do not work properly when sight and motor impaired users use with assistive technologies, like screen readers and screen magnifiers.

3.5.2 USABILITY TESTING

Usability testing is necessary for evaluating newly purposed applications during the prototype phase. Because gestures are already used widely in the mobile based interaction, usability testing helps us to measure the effectiveness of pressure based gestures vs. normal gestures. In an experiment phase, we asked participants to perform some tasks including both multi-touch and three-dimensional gestures to test usability performance, measuring, for example, the number of steps to achieve the goal, and dwell time.

There are three types of usability testing methods: expert-based, automated and user-based testing, according to (Lazar, Feng, & Hochheiser, 2010b) who briefly define all three categories in this project. We will be focusing on expert-based testing with experts who are also familiar with the guidelines of the universal design principle, all along with (W3C) guidelines to determine gesture simplicity. Additionally, user-based testing will play the vital role in making sure that the final application design up is to the standard. In the second phase of this thesis, we will convert wireframes into actual application design with Wizard-of-Oz method define by Lazar, Feng, and Hochheiser (2010c).

According to the literature review, the most authentic and widely used standards for usability testing which focus on effectiveness, efficiency and the satisfaction of the user in the field of human-computer interaction are (Shneiderman, 2000). The (ISO) 13407 was established in

1999 and offers detailed guidelines for the human-centered design process and accessible user interfaces. The ISO standards have detailed guidelines that concern different mapping disabilities with Universal Design principles.

These detailed guidelines will help us to test prototype gestures with user perspectives.(Nielsen, 1995) divides usability into five components

- Learnability,
- Efficiency of use,
- Memorability,
- Error
- Satisfaction

Usability testing will be performed on various tasks, like single touch vs. multi-finger touch-based gestures. Usability testing helps us to understand which tasks are easy to perform.

The aim of this report is to find out the effectiveness of touch-based screen gestures on mobile and tablet devices because touch-based gestures are highly visually and orientationally demanding for all users. In a Universal Design Application, the seven principles play a vital role in developing a universal design app with universal design gestures, to facilitate access to a maximum number of users with disabilities.

To design a fully accessible and interactive universal design application, we have to look into literature about the issues regarding accessibility and usability, and suggestions to overcome these problems. It is a matter of fact that to create a fully functional universal design application is not ideal, but the theme evolved to include Universal Design principles and WCAG guidelines concerning mobile applications.

3.5.3 User Experienced

The user experienced can determine the success of failure of the product(Hosono et al., 2016). The user experience study will make up one's mind that force touch gesture meet the user requirements which we have found in the literature review. It helps us to understand either these gestures are actual need of these targeted group? Did they know about these gestures before this study? The systematic review of user experience evaluation define by Maia and Furtado (2016) reflects the that most researchers preferred qualitative approaches for user experience evaluation. Because user experience is about user perception and response about the product of solution they interact including emotional factors like how the solution inspired them is it easy to use? Make them comfortable? The solution attracts the user? All these factors are necessary for force touch gestures which we have purposed in this study.

3.6 Prototype

The prototype is an essential part tool in UCD methodology because it transfers the concept from the researcher's brains to reality. In the book (Shneiderman, 2016) has suggested new techniques how to test ideas and prototype in the progressively realistic way. Researchers and practitioners in HCI used several techniques like sketching, scenario writing, mock-ups, and paper or functional prototypes. However, in this study, we chose smart prototyping technique Wizard-of-OZ. Inspired by the study (Müller et al., 2016) in which they defined difference between the traditional and new way of prototyping for new technologies especially for user interface design.

At the beginning of this project, we used low-fidelity prototype applications to check the different possibilities for the purpose solution. First, we sketched some prototype ideas on paper. Later we used an online prototype application tool to help design applications online. We checked the interface on a mobile phone by connecting both a laptop and mobile phone over the same internet connection. However, one drawback of this prototype was that these prototype applications still don’t have force gesture templates or support haptic feedback. Still, low-fidelity prototyping helped us to design research question for an ongoing project. In the second phase, we designed a high-fidelity prototype with the aid of smart prototyping techniques using pressure.js API(Application Programming Interface) to simulate real 3D-touch interactions on the iPhone 6s.

Smart prototyping is a new way of designing interfaces for new technologies, and it resolves earlier problems by involving more user requirements. Smart prototyping is part of the participatory design process in the first phase of this research. In this phase, we collected information about older adults' requirements from a literature review and concerning the universal design for aging principles. This method allowed us to understand the aging population's problems while interacting the touch gestures as well as their various concerns and needs. Participatory design is the part of ethnographic research where the researcher focuses on understanding the problems of a targeted group (Lazar et al., 2010b). The three-dimensional touch gestures have been investigated as a universal design solution for the evaluation of this project. Older people could evaluate the accessibility of these gestures by performing tasks on a prototype application. There, gestures are designed with alternative methods of interaction to performing a task on the touch screen. Moreover, these touch gestures helped us to understand the obtrusiveness level of older adults about the new technology.

The Apple (3D-Touch)gesture was announced last year, and it officially has just two gestures for mobile interaction to date.

- Peek and Pop
- Quick Actions

The Peek and Pop gesture has the accessibility feature to recognized web links and gives a preview in a new window. However, its accessibility with screen readers and other Assistive technology needs to be tested with accessibility and usability principles. The second gesture gives shortcuts to icons. For example, when a user presses hard on the message icon, it gives a shortcut to a new message and last message as shown in the pictures respectively.

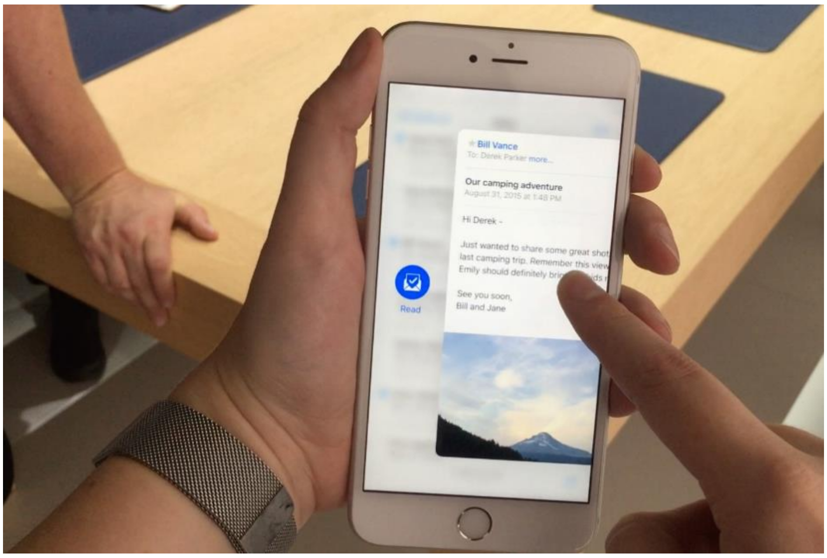


Figure 8 Apple(3D-Touch, 2016) gesture Peek and Pop

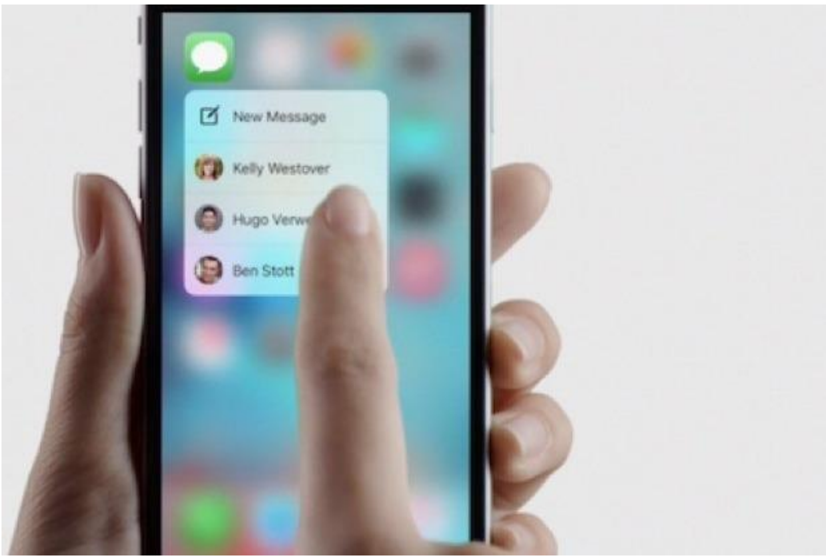


Figure 9 Apple (3D-Touch, 2016) gesture Quick Action

These new gestures are very limited and not supported in every application, but they are becoming more well known. Facebook and Instagram are already using 3D-touch gestures in their mobile interfaces.

Apple (3D-Touch) defines methods for developers to design custom gestures with their SDK (System Development Kit) and configure these gestures in the new applications. This information is available on their website.

Use of the prototype application helps us to determine assumptions and measure if a hypothesis is valid or invalid. Use of the prototype application is the first step to getting experience from the users. This helps the researcher to determine which interaction methods make gesture-based tasks easier, or solve problems. Iterative design contributes to directing the whole development process in the right direction after each repeated cycle of operation. The prototype application contributes to an investigation of the purpose of gestures for pinch-to-zoom and pinch-to-rotate and can offer some improvements in the prototype touch gesture. With multi-touch gestures, there are some failures and drawbacks which we discussed in the literature review, which need to be resolved with new gesture designs. The force touch gesture helps to improve usability and accessibility problems and requirements to satisfy user demands, especially older adults. After designing the force gesture based application prototype, we have to test its functionalities against a defined hypothesis. Force touch gestures now bring new possibilities and features to touch-based interfaces, but there are no official guidelines to test conformance levels aside from expert evaluations with real users.

The prototype application was designed with accessibility in mind. To achieved our goals we tried to follow Universal Design Principles and the WCAG 2.1 Guidelines, which we have described in WCAG 2.1 Section.

The newly designed prototype uses a pressure touch library for designing gestures for touch-based devices. The library is dedicated to utilizing force touch properties. After the initial system design, we focused on different accessibility guidelines for making newly designed IOS applications accessible for everyone, with a prime focus on older people. The accessibility guidelines are divided into two parts. In the previous phase, we elaborated on the different types of mobile applications, and according to the time plan, this phase consists of a web-based prototype with universal design touch gesture, and an evaluation of the gesture control according to the needs of senior users. It was observed that using a web-based application is the most reliable way to evaluate touch gestures in the context of accessibility on any platform.

3.7 Key Facts and Figures about Ageing

- The world changes in surprising ways. However, trend analysis from the various sources shows that the world's population is "Aging" with enormously increasing the senior citizen population in all over the world including Asian and Western countries(Räsänen & Koiranen, 2016).

- The expected population of the world in 2050 is 10 billion people; the data analysis shows that out of five everyone will be age above 60 or older. The live expectancy will be increased. According to World Population Ageing by United (UnitedNations, 2015) more than two billion people over 60 in the world by 2050, and around 400 million over 80.
- A survey conducted by (IBM Cognitive Studio) shows that 46.5% aging people have dementia and memory loss and 16.5 have physical disabilities. This study also indicates that the upcoming new technologies which help this targets to interagate into the society.
- According to the United Nations (2015), there are 7.2 billion people in the world and 10 % of this population has at least one disability.
- According to data collect by Auger et al. (2014) on mobile users worldwide, in 2013, 144.5 million Americans were using smartphones, and it is estimated that by 2016, the number of users will increase by more than 50 million. It is very common for people to now check their emails, use social media applications, and do online shopping with their mobile devices. So this is paramount to investigate user behavior with different mobile gestures to perform tasks more quickly, efficiently and easily. Aging Process

There is no specific definition of age, and there is no discussion in the categorization of ICT users with age as a factor. However, human-computer interaction (HCI) has various examples of research on aging, and this field gives importance to how designers work and include the requirements of this targeted group while designing any user interface. We have tried to include a literature review on aging, with a broad spectrum of issues faced by older adults. Since our research includes both evaluation and design of force touch gestures, we tried to learn about aging and technology acceptance (Obtrusiveness), and the involvement of the elderly in HCI Methodology and Elderly Friendly Design.

The aging process brings negative aspects in human life. It is often described as the decline of physical and mental cognitive abilities. Pang, Zhang, Law, and Foo (2016) Have done research on the affects of aging, and define the decline of functional abilities. Although the aging process is different for everyone, for these touch-based gesture apps, we consider some of the fundamentals changes that occur commonly.

What is aging? How its affect human life regarding Human-computer Interaction with limited capabilities of human (Eriksson, 2016) define aging process very concise and highlights the issues within real world examples. People above 65 have limited sensory, physical and cognitive abilities as compare to younger, but not everyone from this targeted group realizes that they have sensory or physical limitations. What they realize is that smartphones with touch screens are not suitable for them. This leads to frustration while tapping and swapping on a touch interface. This problem can be addressed by the social model of disability because it makes it clear that the barriers, frustrations or challenges faced by an individual with a disability can be resolved with alternative ICT solutions. So User interface design researchers and practitioners try to improve the lives of older adults by developing elderly friendly interfaces by including UD Principles.

To look into the functional disabilities in older adults. First, we have to understand the definition of older adults in different societies(Räsänen & Koiranen, 2016). According to the EU proposal for the accessibility act, the demand for accessible products is increasing dramatically because the population of Europe is getting older. According to the report published by EU, the demographics show that the elderly population will reach 120 million who have a different kind of disability. The aim of the EU directive is to improve the user interface of the ICT system, which is equally accessible to everyone, including the aging population. This research helps the EU directive which stated that manufacturers and service providers worldwide should use different approaches, including design for all, but these need to be evaluated by various standards, such as ISO.

3.8 Age-Related Functional Abilities

3.8.1 Sensory Abilities

"The visual impairment can be briefly defined as the partial or complete loss of vision,"(Bohman)

Moreover, this loss can be acquired throughout life, or it can also be acquired from birth." (Marques et al., 2016) Define briefly that visual impairments have occurred from various medical terminologies, like traumatic to genetics causes. According to the demographics figure from the WHO, there are approximately 285 million people with visual impairment, of which 39 million are fully blind, and 246 million have partial or low vision issues.

Sensory feedback is important for older adults to perform task on the touch screen. The touch gesture which has haptic feedback could help elderly people to reduce percentage of errorsWeiss, Wacharamanotham, Voelker, and Borchers (2011).

3.8.2 Cognitive Abilities

According to (Bohman) cognitive skills are the abilities and process of attention needed to perform any task. Cognitive abilities help elderly people to remember, observe, sort analyze gesture or any task related to interaction (Auger et al., 2014). We can further explain these skills with a suitable example of a task in our usability and accessibility testing.

3.8.3 Physical Abilities

Physical abilities related to touch screen interaction depends on fine motor abilities and finger movements. The touch screen interaction need precise pointing abilities to interact that is why developer has to keep in mind age related characteristic decline fine motor abilities of elderly people Findlater et al. (2013)

3.9 Obtrusiveness

Obtrusiveness define as acceptance of new technologies in older adults Reeder et al. (2016).There has been a gradual decrease in older participant's experience of using newly-introduced technologies Hensel, Demiris, and Courtney (2006). This shows how the older adults can accept new technology based on the characteristics or effects (Reeder et al., 2016). Before testing our hypothesis, we need to recognize the needs of older adults in daily mobile computing, because new technology has a significant impact on the mobile devices. Based on the conceptual framework of Hensel et al. (2006) which defines eight significant dimensions of obtrusiveness for smart technologies, that shows the factor which helps users to accept new technologies. We chose the physical dimension and human-computer dimension for our work.

It is observed that widespread adoption of smartphones has increased rapidly in older adults. This is an excellent trend for human-computer interaction community, which cares to develop systems for all. Smartphones trends are moving towards natural user interface and accessibility because of multi-input functionalities. Hennig (2016) Has highlighted some key features of a natural user interface which make mobile computing easier for all age groups, including older adults, as well as different levels of ability. They have to encounter various problems while interacting with multi-touch devices. However, a lot of older adults does not know how to use gesture inputs with force touch properties. Mobile technology has even higher competence demands to use this kind of gesture, especially for elderly adults. These factors indicate that before designing these gestures, developers and designers must pay attention to educating users how to use these gestures in their daily routines.

3.10 Design Thinking

This research tries to investigate multiple perspectives on the problem statement defined in chapter one, and the idea to make, develop and evaluate the universal design principles with design thinking. In the book, the ABC of research by Shneiderman (2016) reflects the conventional approach of research to do the best research in the human-computer interaction he mentioned in this book that researcher believes that “controlled experiments with a statistical test for significant differences are the gold standards ” for collecting evidence to support their hypothesis.

This technology probing of gesture study tries to follow “Inclusive Research” and “The ABC of research” approach throughout this project. The ideas were borrowed from this two methods define by authors in their books.

By contrast, the “Design Think Approach,” especially in our research, suggested that new ideas in interface design should be evaluated with user requirements and test these ideas in a real environment. Since we have not adopted any specific research method in this study, we used “Design Thinking” approach in the first phase to understand the problems of elderly people mobile interaction. In the next phase, we have designed the prototype with these challenges in mind and tested out hypothesis with the usability and accessibility methods. This phase helps us to collect valuable information about the force touch gestures what works and what doesn’t?

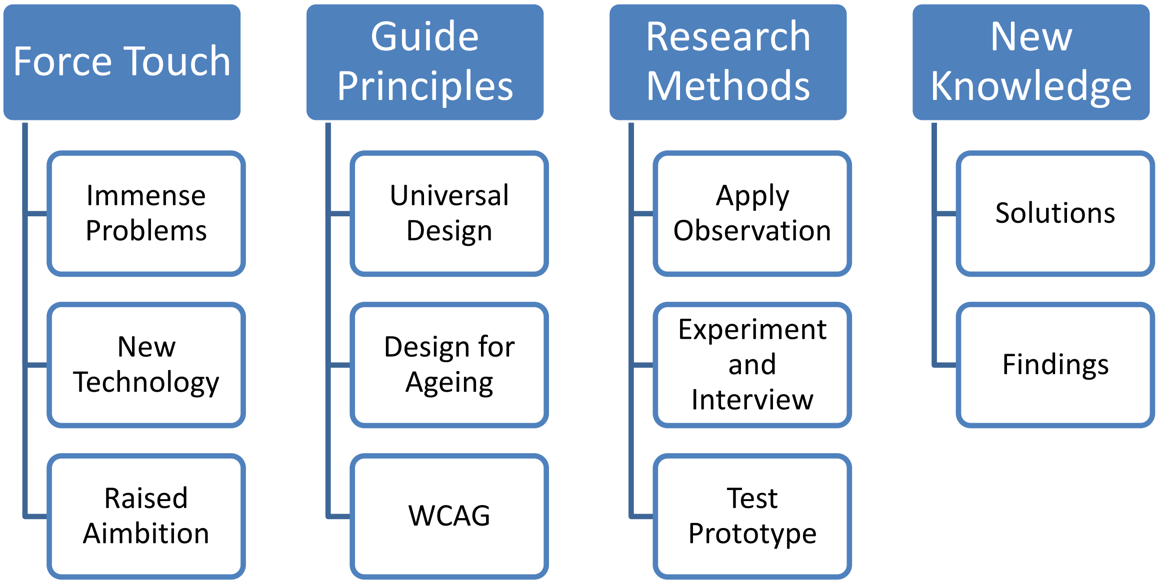


Figure 10 Redesigned the workflow from (Shneiderman, 2016) and Technology Probe Goals

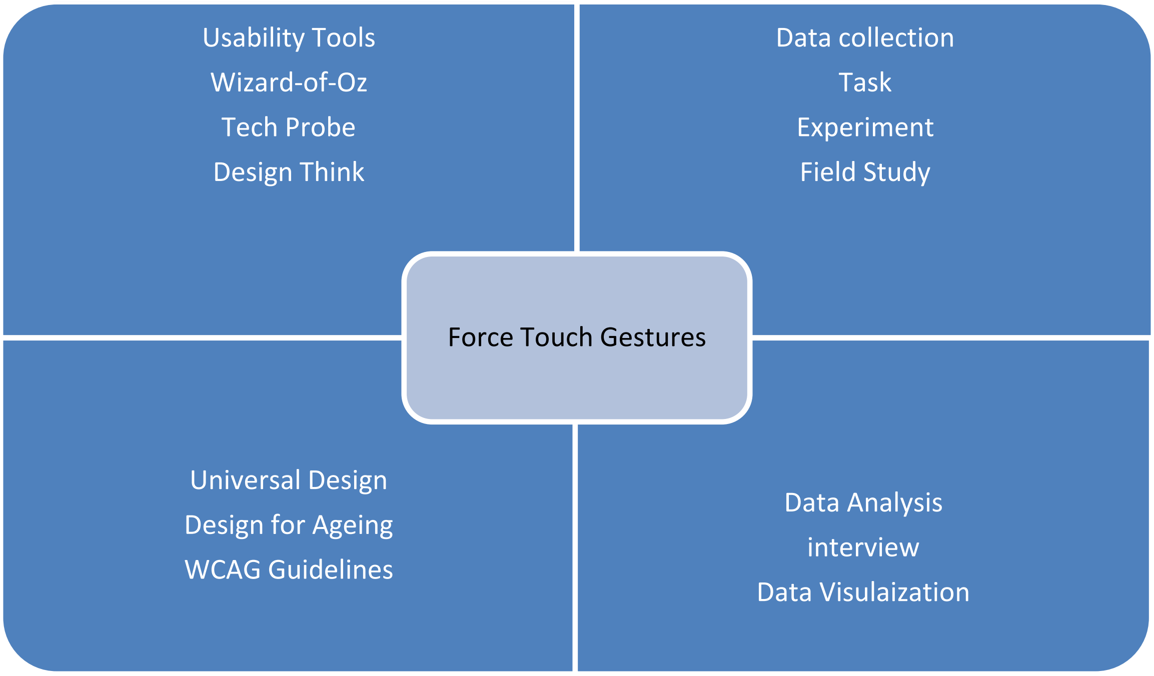
3.11 Conceptual Framework

This section provides the main definition used in this research such as Elderly Friendly Design, Force Touch Gestures, Universal Design Principles, WCAG Guidelines, Inclusive Design and others.

The conceptual framework is essential to identifying the theoretical construct that could provide insight info for force touch gestures for elderly friendly design. It will help us to understand the characterization of older adults use technology, and their abilities to user new gestures interface for touch screen devices. Moreover, this framework helps us to understand how universal design gestures are more accessible and which WCAG principles essential for touch screen accessibility.

This conceptual framework covers the development and evaluation of Idea for newly design touch gestures for elderly group. This conceptual framework design in this study inspired by four theoretical constructs.

Table 5 Conceptual Framework



3.12 Theoretical framework:

The theoretical framework helps researchers to adopt the best data collection methods for their research topic Lazar et al. (2010b). In prototyping applications in human-computer interactions, it is critical to review literature from the relevant field. According to (Lazar et al., 2010b) researchers can find relevant theoretical frameworks from the past research to develop ideas they want to investigate.

In this study, I am trying to identify the physical, mental, and social barriers faced by older adults who interact with touch screens. Moreover, I am working to examine problems they faced while performing gestures to do simple tasks, like pinch and zoom. Research informs our knowledge about physical and cognitive disabilities, such as those that affect the movement of the eye and lead to people being unable to focus on the screen. This impairment is known as cerebral palsy; it is a neurological disorder that affects motor function Trewin, Swart, and Pettick (2013). We can use these this criteria to test touch screen gestures high-level categories for coding scheme. The data collection from interviews or case studies tries to get responses from these categories of participants.

Moreover, Hornung and Baranauskas (2011) point out that before developing any prototype, the problems users faced in the previous version should be understood, and alternative ways evaluated. The main focus of this framework is to develop a user interface that is usable for all, considering the widest range of situations users can face while using the application. Usability and accessibility are considered complex user interfaces because new input methods are developing every day. Hornung and Baranauskas (2011) Focused on connection User Interface modeling. The UI model can be divided further into five sub-models, including the task design, the user model, the device model, the environmental model and the data architecture model. The aim of their research was to develop a system which could be used by different users.

Taher, Alexander, Hardy, and Velloso (2014) Developed a prototype application to test behaviors of pressure based gesture applications. They emphasize checking applications that have more user requirements before developing an actual application. Users may have more errors due to unfamiliarity with the new interaction, so while developing the new interactions methods researchers have to focus on user training before attaining the desired results. We have utilized the user-centred design framework to develop the new gesture. The Design Thinking guideline (de Paula et al., 2014), which is also the user-centred approach, elaborates briefly on the details of general activities or tasks a user may want to perform. The following diagram is formulated from Universal Design Principles (Null, 2013).

The most common impairment that occurs with aging is dyslexia. Dyslexia is a brain-based learning disability that specifically impairs a person's ability to read(Bohman). The research questions addressed in this study are how force touch gestures can help to overcome the accessibility issues in the older population. The study probes the role of new guidelines (W3C) WCAG 2.1 and Universal Design Principles and past studies from the literature review and combines these guidelines to developed a prototype application with force gesture interaction. This theoretical framework used on multiple stages of our qualitative research and help in research design process in the next chapter to frame research questions with the approaches of Data Collection and Analysis procedure. Since we are using the Nvivo software to make categories and theme from the data collection, it will identify the items that need to be coded from the interview and will explain the finding of this study.

3.13 Touch Screen types

The touchscreen has four types which are defined follow:

- Resistive
- Capacitive
- Infrared
- Surface acoustic wave

Nowadays, The most widely used touch screen in mobile technology is a capacitive screen define by (Bhalla & Bhalla, 2010). In their comparison of the different touch screen, The results show that capacitive technology has a clearer display than others. However, it has a drawback as well. For example "capacitive touch screens do not work unless the user is interacting with bare hands or with special gloves with a conductive yarn that allows an electric charge"(Bhalla & Bhalla, 2010). The touch screen has three main elements, a touch sensor which detects fingers, a controller which connects a touch screen to the mobile circuit and firmware. We have used Apple iPhone 6s which has four layers in the contact screen. Nowadays force touch displays are known as (3D-Touch), which is a new kind of interaction screen. It can sense pressure from the human finger more efficiently and in a new way. It has built-in touch sensor in its touch screen. The Figure 11 Layers of mobile touch screens shows layer utilized in this device.

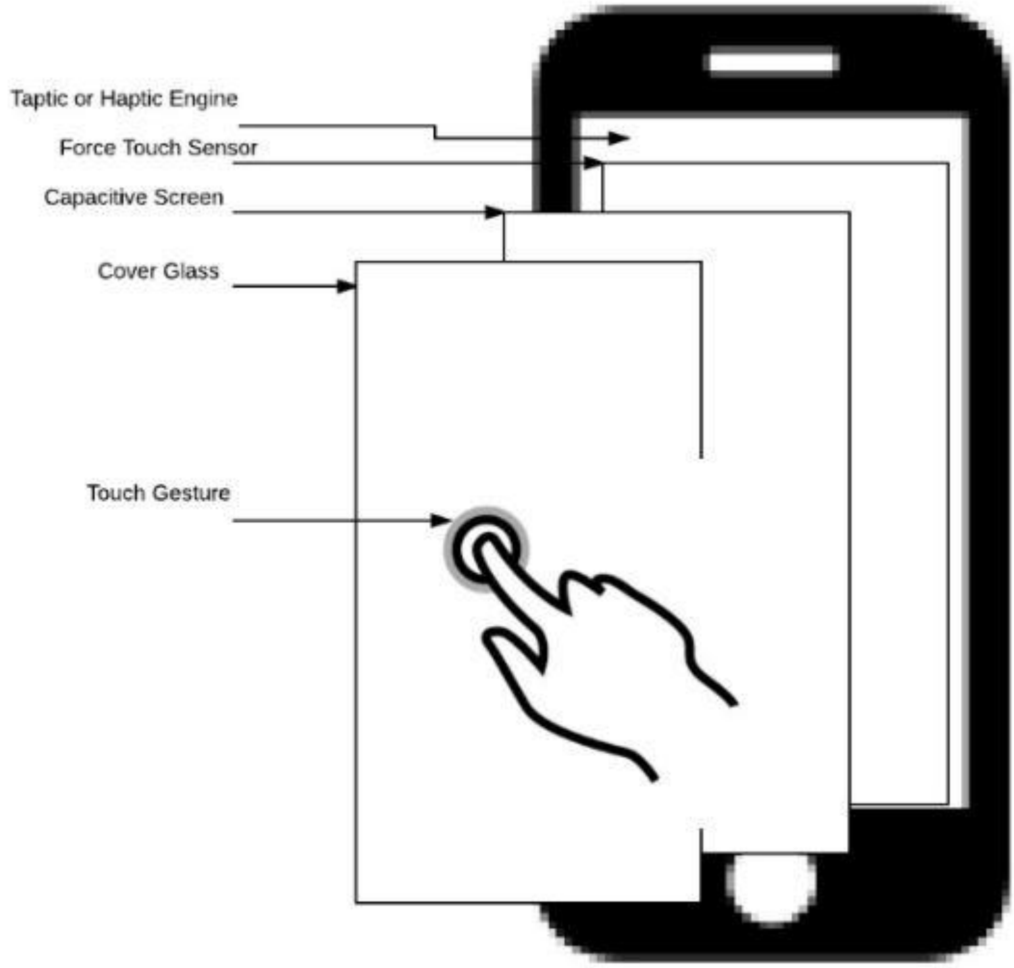


Figure 11 Layers of mobile touch screens

3.13.1 Gestures Possibilities

Force gesture-based applications can be useful for mobile interactions on small screens. In this research, we tried to describe methods where force based gestures could replace or be used as an alternative input method for mobile devices. The main purpose of this application is to make it usable for everyone, even where motor skills can be limited like with the elderly, the visual impaired, or individuals who have any physical motor impairments or situations.

The gesture studies done by Luthra and Ghosh (2015) show that touch-based gestures for the same task are different on different platforms. The Android OS uses single and circular gestures while IOS depends on multiple finger gesture for the same task. In our research, our aim to inspired researcher and practitioner to design new gesture with Universal Design WCAG principles. Like, we encourage HCI community to design gesture with consistency in layout principles. This helps used other platform easily without the need to understand and memorize gestures from scratch.

3.13.2 Taptic and Haptic Engines

Like with normal gestures, feedback is an essential part of the human-computer interaction from old mobile technology, haptic feeds, and now the iPhone 6s, which uses a taptic engine to produce vibrations for the touch-based interactions. (Skubic et al., 2016) Have investigated the challenges faced by the human-computer interaction community concerning older adults and new technologies. Their analysis shows that aging affects vision, hearing and haptic sensing among older adults. On the other hand, the study points to a daily increase in smartphone usage among older adults, and a growing willingness to use new technologies. Force Touch works with haptic feedback to make the interaction of mobile computing more natural. The haptic sense helps the user to communicate with the device. When a user touches the touch screen, the screen can trigger a response in the form of vibrations(Hennig, 2016). The Apple (3D-Touch)touch works with Haptic Engine which can open up computing to older adults, even if they have lower sensing abilities.

The haptic engine is a new technology in the modern mobile computing. It is the technology which makes touch gestures more natural by making them more real. (Davis, 2015) It is the motor which produces ultrasonic vibrations, so human fingers feel like physical buttons on the touch screen. The haptic touch has opened a new door for developers to make applications more realistic, which can help motor impaired people interact with these systems more efficiently.

Trewin et al. (2013) The Study raised questions about potential usability in touch gestures for people with motor impairments. They observed that pinch and swipe, the most common gestures in touch screen interactions, are problematic. There are studies which show that older adults have a widespread problem, cerebral palsy, which affects focus. They also try to estimate the mentality, physicality and visual efforts needed by older adults to operate smartphones. Their study shows that finger slipping problems cause unconscious touches on the touch screen. Touch screens demand more precision to perform a complex task, like selecting or pinching.

This research tries to justify accessibility and usability enhancement after producing design gestures universally with WCAG and WAI Aria guidelines. This research tries to find out the following comparisons.

- Comparison of one finger vs. multi-finger for performing pressure gesture tasks
- Comparison of single hand vs. both hands
- Comparison of Multi-touch slider control vs. Force touch-based gesture

3.13.3 Factors affecting touch Screen Accessibility

The empirical study has done by Taher et al. (2014) shows that factors of force touch which affects accessibility. Investigating force profiles, they studied the effects of force touch on basic touchscreen gestures like zooming, tapping, rotating, typing and panning in a variety of contexts and situations. In the second factor, they investigated contexts and environments of interaction in force touch in different positions, (sitting vs. walking, time vs. untimed, mobile vs. Tablet.) Their study found usability issues while performing tasks with the index finger compare to the thumb. The study also revealed that there is a lack of universal design principle while interacting with both methods. Sometimes users are unable to perform zoom in and zoom out function with two fingers because of big mobile screens.

In another study on thumb-based gestures vs. finger-based gestures, Kim and Jo (2015) point out that various usability issues with thumb-based gestures have been found. They try to evaluate the act by (Chang et al., 2015), who sought to identify the issues in performing tasks with one hand. A new trend shows that mobiles phone come with bigger screens and it is very hard to carry out a task by single hand.

4 Research Approach and Methods

4.1 Chapter Overview

In this Chapter, an attempt is made to describe the research approach, the experiments, observations, and interviews concerning the newly designed force gesture-base. This section will also elaborate on the participant recruitment process, experiment design, and data analysis methods. We performed accessibility testing against WCAG and UD principles with exploratory techniques to test the force touch gestures with the elderly target group. The data was collected with a mixed method, in the form of interviews, observation, and user experience while using the prototype. Grounded theory was employed to analyze the data. The goal of this approach was to assess the touch gesture with Universal Design principles.

4.2 Inclusive Research Methods

The Inclusive Design of ICT means to provide solutions to a broad range of users including disabled, elderly and people who have a different culture. The researchers in HCI still finding new methodologies to work more close with these user groups and Nind and Vinha (2013) purposed an excellent method "inclusive research " which motivated us to follow "collaborative group approach" Although, this research project is not that big but me my supervisor, my classmates and teachers working Universal Design of ICT have common vision to provide solutions to PWD and share their knowledge and practices to each other.

This inclusive research follows the "collaborative group" approach, which involves a systematic review of past studies, principle, guidelines, suggested by expert researchers and inductive analysis of field note data, interview, and meeting transcript. The adapted research methods used in this research are similar to the "Inclusive research" methods.

> *"When people with an intellectual disability and researcher from the universities or other organization do research together it is called Inclusive research" Nind and Vinha (2013).*

Technology is advancing very rapidly, and research needs to adopt new research methods (Lazar et al., 2010a). A Technology Probe methodology was implemented in this research, based on both quantitative and qualitative techniques; the research builds on a conceptual framework derived from the force touch paradigm identified by a systematic review of the literature and theoretical constructs. A comparative analysis of the multi-touch gesture and force touch gesture results will be part of this study. Furthermore, the accessibility issue has been identified by WCAG 2.1 Conformance The study is focused on user perspective concerning modern interfaces. It is about what older adults can do with force touch gestures.

Since (3D-Touch)gestures are newly introduced in the mobile interaction, we have tested our prototype with "Technology Probe" methodology, which aims to put new technologies in a real-world setting(Lazar et al., 2010b). It helps to understand the requirements of older adults. Probes are meant to explore new ideas and include participants in the design process (Stigberg, 2016).

This probe intends to research new ideas and includes participants in the design process (Graham & Rouncefield, 2008). There are three main goals of 3D Touch gestures technology probes, defined by (Hutchinson et al., 2003):

- A Social Goal
- An Engineering Goal
- A Design Goal

To achieve the objective of this study, Technology Probe will be performed in all three phases of this thesis. The goal of this investigation is to examine the real needs of senior users with new technologies. This is because older users have complex stories. Like other target groups, older people are reluctant to use new interactions methods(Liu et al., 2016). Designing new ways for them to interact demands their involvement in an iterative design process to ensure that the outcome is more reliable and that it meets their requirements. For this, we need accurate user experience feedback. Like other target groups, they are different for experiment design. Especially in Norway, older users are difficult to recruit for various reasons. We will elaborate on the recruitment process in the next chapter.

The social goal is to collect data about force touch gesture technology in a real world setting. The aim is to gather information about user interaction behavior with force touch technology.

The engineering goal is a field test of 3D Touch with older adults. The objective of this user testing is not limited to demonstrating the features of 3D touch, but also to highlight accessibility and usability issues faced by this targeted group, and to begin to solve these problems encountered by older adults.

The design goal is to inspire older adults and researchers to think about force touch technology. Force touch technology can play a vital role in creating Universal Design gestures which aim to promote inclusive design for everyone.

4.3 Quantitative Research Methods

This research is more focused on the Qualitative data collection, but we need some usability testing results. We have analysis some usability results. Some quantitative data like age, year of mobile interaction experienced and usability study like user performance against both types of gesture and user satisfaction in percentage.

4.4 Qualitative Research Methods

Researchers in the human-computer interaction field used qualitative research methods to understand the user’s needs, practices, concerns, preferences and attitudes (Lazar et al., 2010b). The qualitative research considers the breadth of the data. We used qualitative methods for nearly the whole duration of this project. This method helped us to identify the categories and the relationship of factors which can improve the user experience of older adults concerning force touch gesture interaction. In the initial stage, we gathered information about the needs and preferences of the targeted group. The data we have collected from the interview and experiment sessions are mainly in descriptive format, and interviews note were acquired manually. Qualitative research methods help us to evaluate the force touch gesture prototype from the user’s perspective and to develop a summative evaluation of the purpose gesture in the prototype. This section explains the details of the qualitative research methods I conducted in this master thesis.

4.5 Research Questions

The art of designing and asking the question in a qualitative purpose is very challenging for any novice researcher (Lazar et al., 2010b) In this study the aim of this session was to derive theory and themes related to force touch gestures in older adults. These question will develop the theory and help to analyze the data. We have asked four research questions in this study, two for sensitizing purposes, where we have compared two gesture techniques like multi-touch and force touch and observed user experience with different techniques(see detailed of techniques in the Data Collection and Analysis). We asked another two questions to help generate the theory that contributes to making the connection between concepts and categories (see detail about connection and categories in the Data Collection and Analysis), like what is the relation between two gestures, multi-touch and force touch gesture.

To reach our goal, we need to answer the following research questions:

1. What are the best tasks for which users can use force gestures?

2. Does applying gesture on a touch screen enable old people to perform force gestures more accurately than a multi-touch gesture?

3. Do force-based gestures make tasks easier than multi-touch gestures?

4. Which gesture will old people consider as an alternative for multi-touch?

For this, we have designed our first prototype, which is an interactive web page using force touch properties. We used pressure.java script created by (Yamartino, 2016) which has pressure touch building properties to develop a Force-to-zoom gesture and Force-to-Rotate gesture. The force touch gesture can recognize position, touch, and the pressure of the user's fingerRekimoto and Schwesig (2006). By applying force to the touch screen. We will elaborate the outcome and the user experience later in the results and discussion Findings.

To inform our prototype development, we have done a systematic review of the literature. We did not find too many articles about elderly friendly gesture design. The Nvivo software provided the categories and themes for the functional abilities, universal design principles and WCAG guidelines about the prototype. In the research (Liu et al., 2016) investigated factors which affect the ability of older people to use smartphones. Low sensitivity of finger touch and slow response of the touch screen were significant factors. Even though there are many ways to zoom the text on a touch screen, including gestures like pinch-to-zoom and assistive technologies like magnification, but our aim is to provide the potential user with Universal Design gestures using force properties. Furthermore, Universally Design means the user can use with the interface without special design or assistive technology. In this prototype we allow the user to press hard on the screen to enhance the text size of the screen and stop where the text size is appropriate for his requirement. This force touch-based gesture is an alternate solution to previous interaction methods. We developed this gesture along guidelines selected from our review of the literature review.

The idea for the development of the first prototype is to give independence from assistive technologies and self-esteem of senior citizens. For developing the prototype, we have to consider the aging factors which affect the health of old people. Another element which can affect our prototype is muscle fiber which decreases and shortens by age. The idea to replace pinch-to-zoom gesture by force touch gesture. This interaction technique can help to fulfill most of the Universal Design principles by allowing single finger with less tapping to complete the task.

The experiment design section is the part of the technology probe which helps us collect data from the field study, inspire users with the new technology and solve their problems with new design methods. This section elaborates on the method used in experiments, such as how old people interact with our prototype. Therefore this research will investigate further into the sensor cells issue faced by old people, and consider how force touch interactions can help them to cope with various impairments. Our findings will enable us to understand how to develop ideal force touch screen gestures for senior citizens.

4.6 Research Design

In the research design stage, our conceptual framework helps us to design the research questions on the older adults's perspectives about the force touch gesture. We applied both qualitative and quantitative and mixed methods techniques to collect the data. Experiment with a prototype for usability testing gives Quantitative Data. The interview with the participants gives us text-based data which we had analysis with Nvivo software to quickly organize and categorize qualitative data.

In this section, I describe my research approaches, the target group and how participants were recruited for the research activities.

- Experiment design
- Interview
- Pilot testing
- Interview guide
- Participants

4.6.1 Experimental Research

Experimental research is widely used in many studies in Human Computer Interaction (HCI). We have chosen this research methodology because we need a control or manipulate experimental conditions so we can compare two interaction conditions to each, considering different factors. According to (Lazar et al., 2010b), experimental research is a detailed and relational investigation. For our prototype user experience, we have designed control experiments to assign participants different conditions related to the touch-based interaction. We want to test our hypothesis, which has a design in the early planning phase.

This part describes an experiment with which we explore force gesture-based interactions with small screen displays that sense the amount of the force applied to the screen.

To accomplish our goals, we selected some older adults with iPhone user experience and performed a semi-structure interview study. This session helps us to collect primary data collection; the semi-structure interview starts with some basic questions about the interviewee's background and an introduction to the experiment or research. The semi-structure interview follows fly-on-the-wheel terminology to let the participant's conversation go where they want. We then ask questions to clarify details probe their answers (Lazar et al., 2010b). Our measuring unit for this study concerns the abilities of the elderly, such as cognitive ability, physical ability, and learning ability. We have defined some assignment methods according to the way in which the experimental units are assigned different treatments. For example, we have compared force touch gestures with multi-touch gestures. So the gestures here are the treatment units of the abilities of older adults to perform the task, and the comparison of different interaction methods are the assigned methods.

4.6.1.1 Pilot studies

In this research, we have conducted pilot studies in the Master Room in our College, where all Universal ICT design students studied together. We helped each other in various pilot studies, from experiments to consent forms, to research experiment designs goals. To the best of our knowledge, everyone was working on a first attempt to study and collect data on the accessibility of ICT systems. In my pilot study, I tried to use their knowledge to design an experiment that was reliable and comfortable for the actual participants of this study. Pilot studies in this research help us to explore and identify themes within the elderly friendly mobile interface.

(Lazar et al., 2010b) Describe pilot testing as an essential step before starting any research. Pilot testing will help researchers understand all the inside information which is significant to conduct any data collection. It will address some important issues which researchers may have missed during the initial experiment design pattern. Appropriate planning and preparation are, of course, essential. In our experiment design, pilot testing, and interview sessions with research colleagues and participants helps to developed a new idea to probe the answer from the participants. Pilot testing sessions contribute to identifying questions that were hard to understand. It can also help to include important and non-important content from the questionnaire form after pilot testing.

In Lazar et al. (2010b) Chapter two "Experimental Research" working with research participants with impairments, it is mention that researchers must address all the details with appropriate planning and preparation before starting the actual experiment. To achieve better results, pilot testing with the researcher's colleagues and friends can better prepare the researcher for the real interviews. Further, pilot testing gives a better model for the possible length of the interviews. This allows the researcher to ask the participant to participate in the experiment and provide a calculated time frame to mention on the consent form. Pilot studies help us unveil some problems in the prototype design as well. In the initial phase, we designed a gesture to rotate the picture at speed about the force applied to the touch screen. While doing the pilot testing, one of the participants was confused where he has to stop. Then we provide the instruction in Prototype where should participant stop rotating.

4.6.2 Interview

For our data collection, we chose to interview while conducting our experiment with the participant. We have conducted the experiments with pre- and post- interview questions with the participant about their user experienced. The interviews were semi-structured and consisted of both open-ended and closed-ended questions. These interviews were helpful for gaining information about force touch user experience from older adults. This session gave us expanded information to help understand their needs, perceptions, and concerns.

The interviewed aimed to gather the reflection and evaluation of accessibility guidelines for force touch gesture with regards to elderly people user experience. We help from theoretical models of disabilities, especially Medical and Social Models, to get an answer from the elderly population about whether to use this technology assist them to interact with a smartphone or they are facing more problems? The evaluation methods have been composed on user experience, task-oriented usability, and accessibility testing.

Lazar et al. (2010b) Suggested HCI researcher and practitioner that in the interview session the interviewee has to overcome favorable response from the participant. We have experienced the same situation in our first and second interviews. When we let the participants know about that evaluation prototype was designed for older adults, they tried to give overly favorable feedback. Then we changed our experiment design to get more credence to critical remarks.

The interview has a capability to “go deep” to get the wide range of answers with concern to questions about the research(Lazar et al., 2010b). In our research, pre- and post- interviews helped us to get detailed answers about the force touch technology and gesture designs in the prototype.

The weakness of the interview format was difficult to capture. We made some written notes while conducting the interview with the participants.

4.6.2.1 Interview Guide

The interview guide aimed to investigate how participants experienced the interaction with a prototype for force touch-based interaction. When meeting with the participants for an interview, I reviewed the purpose of the study and the interview process. An interview guide was constructed as a tool describing how to engage participants in probing the answer of this study. In general, the UD principles and WCAG guidelines often describe their terminology technically. Unfortunately, many of these are not understandable and comprehensible for older adults. Therefore, the questions of the interview did not ask directly for UD principles or WCAG guidelines. We focused on avoiding technical terminologies from the participants. We designed our interview questions to be understandable for older adults. However, still maintained our focus on the intention of the guidelines. For example, instead of asking:

"Do you think these gestures fulfill UD principle one, about equity, or WCAG principle one, perceptive?"

We posed it this way: “Did you find any gesture difficult, are you able to perform the gesture with one hand, or “are you able to perform the gesture with a single finger?”

The interview guide was designed to cover the following five sections.

- Rapport establishment
- Force Touch
- Universal Design
- Accessibility Guidelines
- Barrier in design

Rapport is an essential part of any experiment design where an interview is the primary data collection source. To establish rapport, we do the pilot testing before starting the actual interview to identify a real question flow and make the interviewee feel comfortable and at ease. For acquiring the actual user experience of the newly design interaction method, it is vital to conduct the interview in a professional and friendly environment.

In phase one we defined some research hypotheses that can be investigated in the experiment. We conducted an exploratory study on older adults to discover which gestures will suit them, to replace multi-touch gestures. In interview sessions, we briefed the users on how to use the force touch gestures with the aid of some prototypes before conducting the experiment.

To test the accessibility and usability of the purpose gestures, we developed the prototype with a Wizard-of-Oz methodology(Lazar et al., 2010a) to simulate the final user behavior as closely as possible. A qualitative study was part of the technology probe for a gesture of this study. In this way, the user experience with accessibility issues when interacting with the gesture was recorded with a screen recording tool. We took advantage of this approach in experiment sessions with older adults. The literature review shows that older adults capabilities (sensory, cognitive and physical) vary when using touch screens, as does their experience level with using touch screen devices. The qualitative interview helps more than quantitative usability testing regarding older adults' needs concerning touch screen interaction. We have conducted interviews while experimenting with the prototype. We performed an experiment with nine older adults to understand how they can interact with new force touch gesture designs. We tried to understand how older adults coped with the demand of the force touch gestures. They interacted with force-to zoom gestures for increase text size and force-to-rotate for photo rotating gestures with new and old methods and with different primitives and target sizes there.

4.6.2.2 Training Session

We held a training session to allow the subject to become familiar with the new gestures to comfort them before beginning the experiment. In the training session participants were informed about how the interface works. There was no time frame on the training session, and the participants were allowed the time they needed to interact with the force gestures. This helped to make the research more reliable and produced more valid results.

4.6.2.3 **The Tasks**

We gave the four tasks to every participant:

1. The first activity involved increasing the text size of web page content. First, we allowed the users to increase the text size with a force gesture(Force-to-zoom).

2. The second activity was to interact the same objective using the old, conventional, multi-touch gesture(pinch-to-zoom).

3. The third activity was to rotate the picture clockwise with force touch gesture(force-to-rotate).

4. The fourth activity involved rotating the picture with the multi-touch gesture(pinch-to-rotate).

4.6.2.4 Recruitment of Participants

The study was originally designed for older adults, so our aim was to recruit participants above 60 who used smartphones. The criteria were reviewed and asked as part of the recruitment script Appendix 1: for each participant. Each participant signed the Appendix 2: consent form beforehand.

To find a diverse group of older adults, we considered the various option in Norway and Scandinavian countries. I observed some older people who used iPhone in their daily lives, but I wanted to establish a connection with individuals who are strangers to me to get a valid user experience. I also wanted to cover the different points of view from the participants.

We used snowball sampling for our recruiting process mentioned by (Lazar et al., 2010b), which helped us contact potential participants within communities and organizations. I put some brochures in a community hall in Norway and Denmark which had my contact details (Phone number and e-mail address) to connect people to tech savvy older adults who like to be involved in new technology research.

We looked for people with diverse backgrounds, like retired teachers, cab drivers, and retirees. We started searching for our participants in Norway. We selected an organization that works with rehabilitation for the elderly. We focused on covering a broad range of individuals with different experiences in their professional and social lives. As a result, 9 participants were found; 6 male and 3 female. The youngest participant was 62 years old, and the oldest 79 and the average age was about 71 years.

Upon a satisfactory initial screening, I met with each candidate at a mutually agreeable time and location to review the details of the study. We observed that a significant number of older adults feel tired while traveling via public transport, or after a long drive. To make the participants comfortable and fully attentive for the test, we made a point to meet them personally at their preferred locations, such as cafés, or in their homes. This helped us get enough time from the participants to conduct the experiment appropriately.

The semi-structured interview was designed for observation of the experiment. The interviews were designed with a qualitative approach to help us record feedback about the newly designed gestures for interacting with touch screens. The prototype interface was presented to the participants to observe user experience concerning their daily interaction with touch devices. The users were asked to used force touch-based gestures with the web page we designed for them. We encouraged them to use single figures while pressing on the screen. While the participants answered the questions and interacted with the devices, screen recording was running in the background to record their interactions and expressions. In the second stage of the interview, a list composed of simple and complex gestures was presented to the participants to ask them about the possible commands that could be created based on force touch-based gestures.

Table 6 Participant Data

Participant	Age	Sex	Mobile phone
S1	62	M	Android
S2	65	M	Apple
S3	61	M	Nokia
S4	71	F	Android
S5	82	M	Apple
S6	77	F	Apple
S7	62	F	Apple
S8	69	M	Apple
S9	71	M	Apple

In the introduction part of the interview, we collected data on the participants' age, sex and mobile platform used in daily routines. This is why we have divided this theme into three categories: exposure to mobile phone and touch gesture, why they use this platform, and what kind of tasks they performed in daily mobile computing.

4.6.2.5 Platform Presence

Six out of nine participants used Apple mobile phones and preferred IOS over Android and Nokia smartphones. They had mixed feeling about Apple devices, and they felt it was easy for them to use the platform. Two participants used Android mobile phones, and one used Nokia Lumia because it is cheap and has big icons.

4.6.2.6 Reminiscence

The final part is reminiscence about the mobile devices. Four out of Nine users shared their stories about why they chose specific mobile devices. One of the participants shared this story: "She used an Apple iPhone because it was a gift from her daughter, and she uses iPhone to Facetime (Video call for phone users) call with her grandson and granddaughter".

4.6.2.7 First exposure

This section helps to provide detailed information about participant background with engagement to the mobile devices in their daily routine. Three participants S2, S5, S6, S7, S8 and S9, used iPhone with different models ranging from 4s to 6s. These participants had used smartphones between 3 to 7 years and were considered the most experienced mobile phone users in the target group.

Participant s6 had an iPhone 6s, but she did not know about the three-dimensional touch gesture because she had upgraded her mobile one year ago, from a 4s to a 6s, just for screen size. She has not found any information about this gesture in the user guide. That is why this gesture was not discoverable for her before this experiment.

4.6.2.8 Expectation

Force touch gestures are different from multi-touch gestures, and even younger people are not entirely aware of them. Multi-touch gestures require more than one finger for touchscreen interaction in most cases mentioned by Bobeth et al. (2012), but force touch gestures usually require only one finger, especially the gestures we purposed for various tasks. Two figure gestures usually take more time with single figure gestures. We have an expectation that force touch gestures will perform better than older, conventional gestures.

4.6.2.9 Device and Apparatus

The study is conducted on an Apple iPhone 6s (3D-Touch)mobile phone. The size of the screen is 4.7 inches, and it has a resolution of 750 x 1334 pixels. The reason we chose this mobile is that it was the only mobile device which supported Force touch or (3D-Touch) when we started this project. It also supports both multi-touch and force touch simultaneously. It has capacitive touch sensing, which supports force gestures. It can also work with a glove with a limited kind of material. In the experiment, we utilized both touch sensing types for user experience. Participants were allowed to use with any hand (Left or Right) and any suitable position.

4.6.3 Task

Before starting the experiment, we briefed participants about force touch gesture usage. We have developed the manual for how to operate force touch gesture, provided in Appendix 5. This guide was designed to make sure that each participant gained the same level of experience and knew how to use force gestures and understood the functionalities offered by the prototype. Before starting the experiment, this manual helped participants to understand the scenarios.

The task was designing with a split-plot design, which is a combination of between-group design and within-group design according to (Lazar et al., 2010b). The participants of this research have diverse backgrounds and knowledge of the touch screens.

4.6.3.1 First Task

Force touch gestures are new for most of the older adults. While conducting new interaction methods with this age group we felt anxiety among them. To reduce it, we had to introduce the touch gestures in easy manners. For that purpose, we used newspaper CSS (Cascading Style Sheets) because lots of older adults use a mobile phone to the read the newspaper.

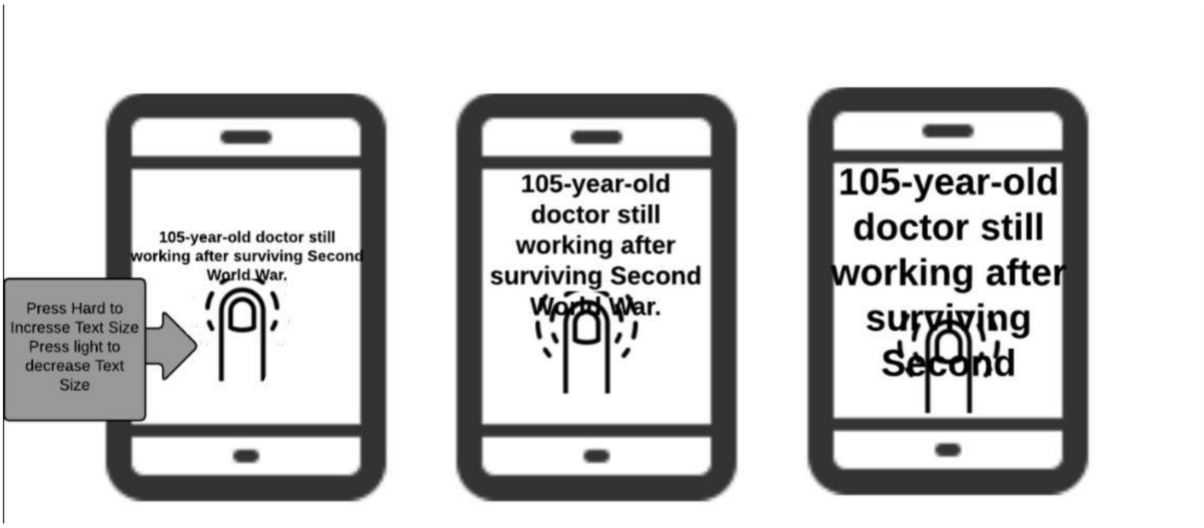


Figure 12 Task 1 Force-to-zoom

4.6.3.2 Second Task

We have put the picture on a 0-degree interval around the initial position for the task. The force touch gesture button can rotate the picture from 0° to 360°. In this experiment, the user should exert the force button with one finger.

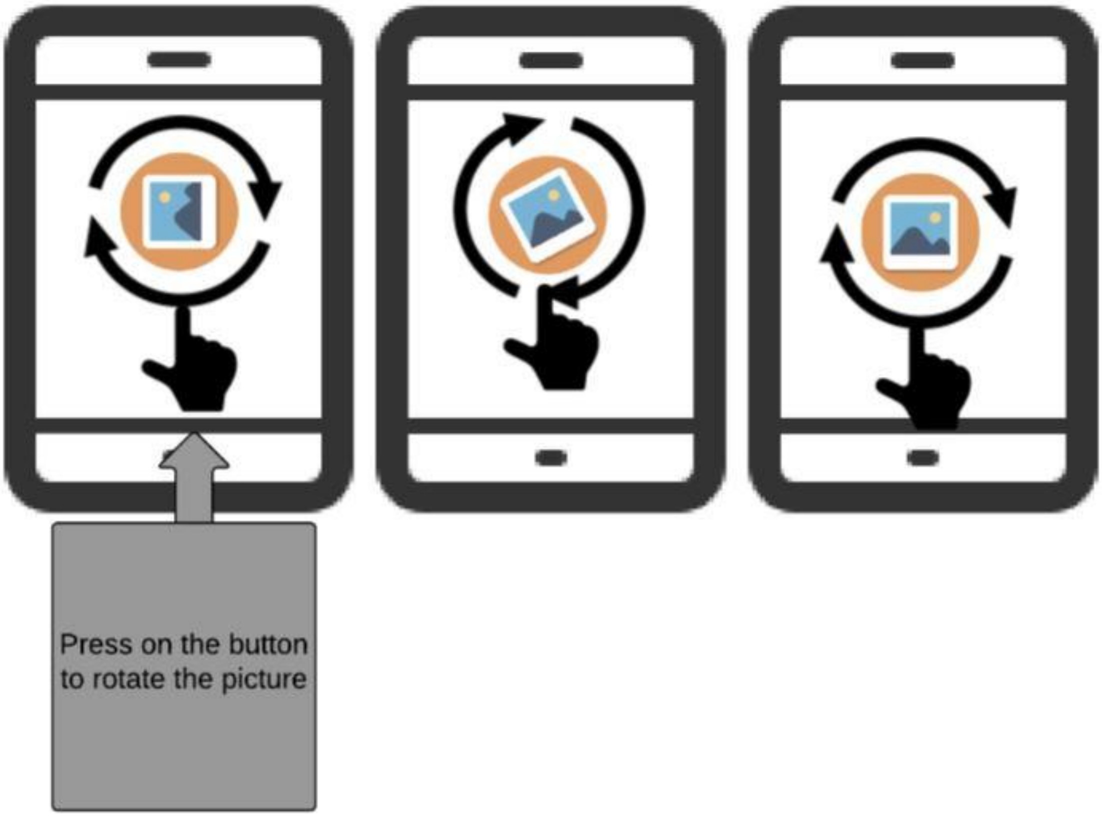


Figure 13 Task 2 Force-toRotate

In the literature review, we have found that different touch increase devices demand different motor and cognitive skills. The aim of this task to evaluate the UD and WCAG principles for making this gesture accessible for older adults with the lowest motor and cognitive load.

4.7 Observation

4.7.1 Think Aloud Protocol

In a guest lecture on new technological support for older people and people with disabilities (Gallagher & Petrie, 2013) encouraged students to use the think-aloud protocol to help the researcher probe better results for their research. In data collection, when I was trying to focus on accessibility issues in three-dimensional gestures, I tried to let my users say loud everything they were thinking and trying to do while interacting with the prototype.

In the user testing session, we found that three-dimensional gestures are new for older adults. To tackle this situation, we implanted the task-based approach in the newly designed prototype. The aim of the think-aloud protocol was to allow the users to understand the three-dimensional touch gesture. We gave a brief introduction about the 3D-touch gesture to the participants and gave them an activity to perform the task.

The primary target group was older people for this study. However, to test the accessibility with the blind user, we have not found any participant with fully vision impairment. That is why we conduct a single experiment with an expert blind user who has an experience of 10 years in using mobile phone with ATs. That participant helps to evaluate the accessibility of force touch gestures with a screenreader. In WCAG 2.1 the guidelines help us to test these gesture for a blind user with conformance level.

In the prototype evaluation, we asked the participants to perform some tasks on mobile devices. For each task, we developed task related questions, which I asked during the task solving session, taking some notes on how a user can interact with the interface and which interface created an obstacle for the participant. We also had software running in the background to capture the movement of the gestures and inputs on the screen. Quantitative measures, like effiency and accuracy have been recording in the software.

The highlights of this observation include:

- Familiarity with the force touch gesture in the older adults
- Familiarity with the research topic in the context of the research

Participant S1 is 62 years old and enjoying his pension life in Norway With no specific impairments so far. We met at the local Café in the Oslo and discussed new technology on the market. He has been an iPhone 4s user for the last four years, and his friends help him to use touch screen phones. It took four years for him to use touch screen gestures properly. When we asked him about the force touch gesture, he had a much better idea after 20 minutes.

When conducting the experiments with the participants, we encountered very few problems regarding the force touch gesture. We conducted a long session about the gesture after the experiment, and most of the participants gave a positive review about the new gestures. Participants first attempted to use their old gestures, such as the two-finger pinch, because they had familiarity with it. The problem we encountered was that participants could not recognize how to make the text return to its original position after reading the zoom-sized text.

The results so far from the data collections showed that force touch gestures are a good alternative to two-touch pinch zoom because elderly adults move slowly with touchscreens.

4.8 Usability Testing

(Lazar et al., 2010a) Reflects on new methods of usability testing, as compared to traditional and conventional methods. Emerging technologies bring new ways of interaction to the field of human-computer interaction. In the literature review, we came across new approaches to usability testing. Researchers are now combining multiple methods to get more reliable results.

The two newly introduced methods in the field of HCI are:

- Technology Probe
- Wizard-of-Oz-Testing

Both above methods have the potential to used in our usability and accessibility engineering settings to discover relevant results for 3D-touch gestures.

4.8.1 Wizard of OZ

The second famous usability method in the field of HCI is Wizard-of-Oz(Lazar et al., 2010b) which can simulate functionalities which are not available in mainstream technologies but can be provided in advance in a prototype application. In our case, we have designed some force touch gestures which will be used in future as an alternative type of input in mobile interaction. This usability session can revisit the mobile interface guidelines from Universal Design principles, and WCAG to test the usability of new design gestures. Wizard-of-Oz methods can be very useful when technology cannot be deployed for various reasons like cost, lack of hardware and lack of knowledge of software coding. It is a very useful way of testing the future technology(Lazar et al., 2010a). In this study, we can test these gestures with UDP and WCAG guidelines, and check the feasibility and user acceptance, especially for "older adults."

In this section, we will define how we will perform user testing to evaluate the best gestures for seniors, regarding performance.

The core theme of this project is to conduct qualitative research, but for performance measurements, we have to carry out some usability testing as well. The idea is to conduct summative usability testing for the force touch gestures. The usability testing will allow us to redesign these gestures with more improvements after getting the results.

(Ruzic et al., 2016) Developed the universal design mobile interface guidelines for an aging population, which addresses our abilities issue when developing a mobile application for older adults. They have purposed different strategies to analyze the user interface, specifically for older adults.

We have experimented with 9 participants, where Six were male, and three were female. The youngest participant was 63 years old, and the oldest 79 and the average age was about 71 years. Five were considered to be expert users, and four were deemed to be novice users, as explained by the criteria in the recruitment process. According to (Findlater et al., 2013) psychomotor performance is only one aspect of usability. In our study, Universal Design Principle 1,2,3 and 6 also describe the importance of fine-motor usability testing with touch screens for easy use. As mentioned before, the goal was to test the learnability of force touch gesture interaction for older adults, and also to compare the user experience of force touch gestures with conventional gestures. Comparative analysis based on efficiency, effectiveness, and satisfaction are considered the main criteria and are explained in detail in the data collection chapter.

To increase the reliability of the usability testing, we have applied think aloud methods to ask participants what they are experiencing on the screen. We defined the role of the "Think Aloud" technique when the targeted group is elderly people, in the last chapter of the literature review. We also recorded the movement of fingers when interacting with the prototype using a screen capture tool. Eventually, these two methods provided access to both quantitative and qualitative data for the evaluation of force touch gestures.

4.8.2 Hypothesis

H0: There is no difference in user satisfaction concerning zooming usability between multi-touch gestures and force touch gestures

H1: The force touch gesture has higher user satisfaction concerning zooming usability due to it being faster than a multi-touch gesture

Table 7 Usability Testing Results

Participant	Time performance(sec)			
Participant	Force-to-zoom	Pinch-to-zoom	Force-to-rotate	Pinch-to-rotate
S1	6	5	3	12
S2	7	6	4	12
S3	5	8	3	14
S4	10	7	5	15
S5	9	10	9	13
S6	9	7	8	12
S7	7	6	9	11
S8	9	9	7	12
S9	7	6	7	11
Average	8.333333	7.111111	6.111111	12.44444

Figure 14 Force Touch vs. Multi-Touch Satisfaction in Percentage

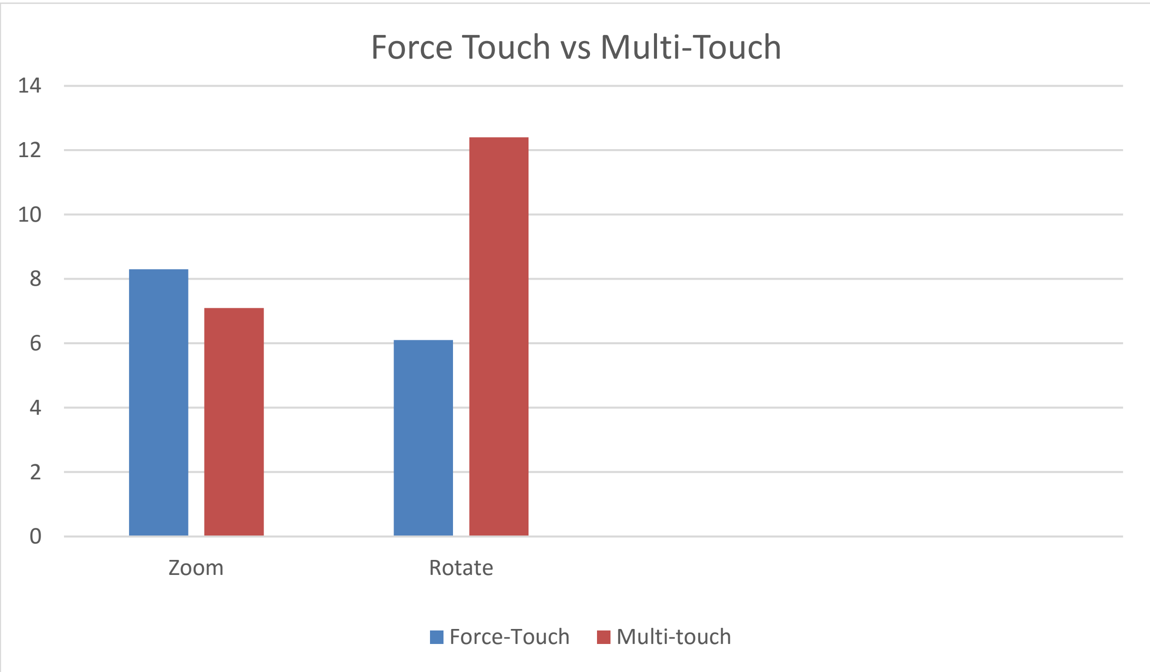
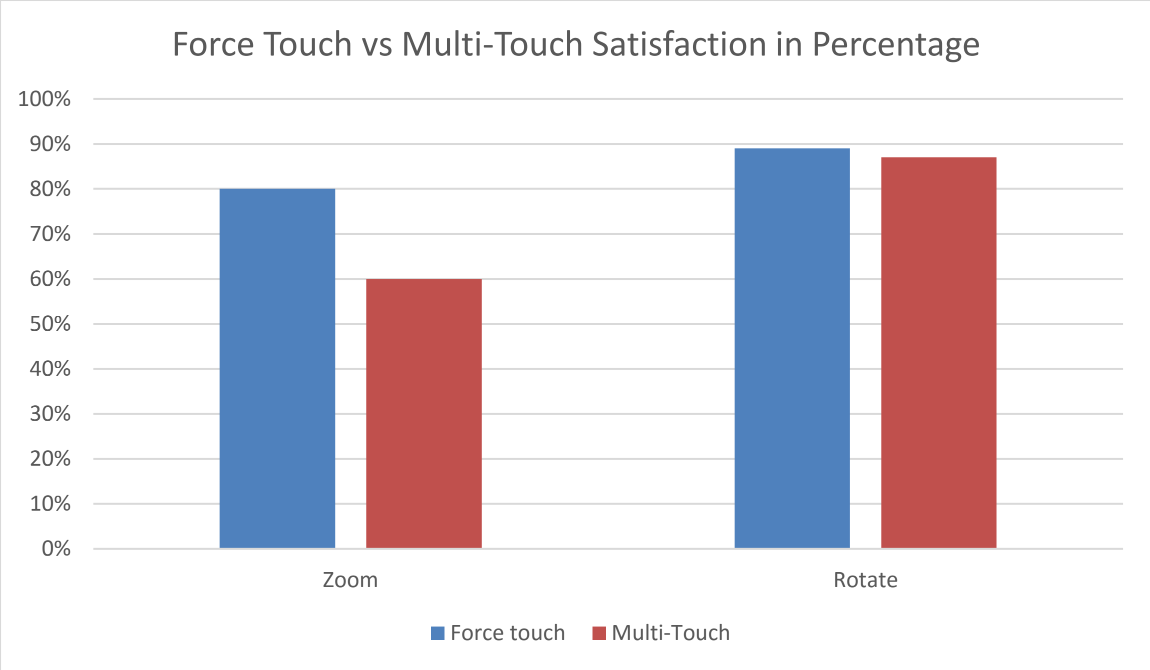


Figure 15 Time Performance of Force Touch vs. Multi-Touch user performance



The screen capture tool “Ux Recorder” developed by (Labs, 2017)helped us to keep track of user movements on display. According to (ISO, 2016) the standard, the basic usability requirements must match the guidelines. The methods were motivated by (Kokemor & Hutter, 2016) the aspect-oriented approach to user interactions with mobile devices. Therefore, all research should focus on these research questions, which arise for a variety of interaction modalities available in mobile devices nowadays. We have concentrated our usability testing on these methods. When and where do users interact on the screen? Which gestures does user use or try to use? Are the basic usability and accessibility requirements described by (ISO, 2016) and (Accessibility, 2015) fulfilled? To answer these questions, it is necessary to use a new tool, which helps them to analyze the results in detail. There are many automated tools available for website usability and accessibility testing available on the internet. However, the literature review shows that there is no automated tool available for mobile accessibility testing especially for native and application(Wille et al., 2016). Memorability and discoverability testing was analyzed in chapter 6. The results in Figure 15 show easy-to-use comparisons. They indicate that force touch gestures are relatively slow as compare to pinch-to-zoom gestures. One of the main factors which influence this is a lack of prior knowledge about these gestures. In our interview session, participants made the same comment that it was difficult for them to learn this gesture. In the interview session, most of the users mention that they did not know where to press hard to increase the font size. The performance of the force-to-zoom gesture was affected by discoverability. In the second comparison, this shows. Clearly, the force-to-rotate gesture performs excellently as compared to pinch-to-zoom. The main reason behind is that this gesture is discoverable, memorable and easy to perform with the force touch button. In the interview session, users mentioned that they tried to rotate maps to find the right direction. Here, force-to-zoom showed its strength.

5 Data Collection and Analysis

5.1 Chapter Overview

This section outlines the tools and techniques of data collection methods to answer the research problem of this thesis. This section discusses which data collection will be suitable for research, how to collect it, who will collect the data from the participants, and when data collection sessions will be held. It also discusses ethical methods of data collection in Norway. The aim of this data collection should be to attain reliable and valid research to fulfill the hypothesis and research design.

5.2 Data Collection

The aim of this section is to collect valuable information about force touch-based gesture user experience about universal design principles. The series of activities involved different techniques of data collection from the diverse group of participants. Initially, the project idea was to collect information from the elderly population. Later we had to collect some data from a blind user as well, to fulfill the research criterion and one of the evaluating Universal Design principles, "Design for All." There are several techniques which we have applied during the data collection phase already described in detail in Research Approach and Methods.

In this research, we have focused more on qualitative data collection, like interviews and observation of older adults. Data analysis is part of the technology probing procedure for force touch gesture design and evaluation. The first two goals, the social science, and engineering goals help to collect data from the literature review about designing a gesture according to user requirements and then conducting a field test with a real user. The data analysis and the findings of this study will be part of the design goal. The design goal aims to inspire users and researchers about the outcomes of the results of force touch interaction. The finding can help researchers and designers to develop more ideas to use force touch gestures in touch mobile interaction. This analysis can also help them to follow the Universal Design Principle and guidelines specific to their targeted groups, such as those with who are blind, or those with motor or cognitive disabilities. According to Corbin and Strauss (2008), qualitative data analysis has three stages.

- A group of users

- A specific technology
- Interaction behavior in a specific context

The data collection process started in Phase II of this project and was conducted until Phase III, which was a part of the data collection cycle to make sure to validate this research.

These data collection methods attempted to cover all three goals defined by the technology probe. First, the social science goal of collecting data about the use of force touch gestures in a real world setting was addressed by using these gestures while reading the newspaper on a mobile device. Second, the engineering goal was tested using the gesture in the field. This goal helped us to consider and test against the UD and WCAG guidelines. We examined methods for bringing these guidelines into practice and applied test procedures to evaluate conformance level with these guidelines. Third, the design goal was addressed by our attempt to inspire users and researchers to think about of 3D touch interactions, and how new ideas can be converted into real-life gestures for older adults.

Data Collection technique	First Phase	Second Phase
Observation	In the first phase, we met with a senior citizen from Norway who held a session at our school. Here, I got valuable information about a senior organization in Norway that works with older people. In that session, I got contact details for some participants and held some meetings. The primary goal of the data collection was to observe the participants using touch screen gestures, both old and new. I was an unobtrusive observer to identify the problems faced by older adults	

Data Collection technique	First Phase	Second Phase
	during their uses of force touch gestures in a natural setting. I recorded my observations in my notebook.	
Data from Screen Capture Tool	I used the Screen Capture tool known as UX Recorder for iPhone. This helped me record information about the execution time of the gestures.	
Focus Group		In the second phase, I attended the meeting of 7 participants in Denmark. This session helped me to verify my research questions one more time. In this focus group session, I gained information about the participants' touch screen skills. This helped us to get a full exploratory view of the participants to identify the problems they face with force touch gestures. I mentioned the skills test in my consent from.
Semi-Structure Interviews	In the first phase of this project, nine participants were interviewed. Six of	In this session, I tried to involve some other targeted groups, as a blind user, to

Data Collection technique	First Phase	Second Phase
	them were male, and three were female.	test the 3D touch gesture with Assistive Technology.
Think-aloud Protocol	Since the 3D-touch gesture was new for everyone, I tried to conduct usability and accessibility issues with a different target group, especially vision impaired people. I contacted blind people to share their thoughts on the various portals and to share their reviews of the new technology. I contacted an expert blind user who has been using the 3D-touch gesture since the launch of this model. He shared his thoughts that these kinds of gestures are undiscoverable for the blind.	

We have collected both qualitative and quantitative data to test the hypothesis we set in the first phase of this research. We have collected interview data with a set of qualitative semi-structure questions to examine the Universal Design Principle followed in the three-dimensional touch gestures. The research focused on the significance of Universal Design principles while designing mobile gestures to create an elderly friendly interface. The data collection had three phases. First, we tried to explore details about the smartphone usage and know-how of the force touch gesture with among users. In the second phase, we asked some semi-structure interview questions to probe and test hypothesis questions for qualitative data collection. In the third phase, we conducted an experiment to help gather both qualitative and quantitative data, which was part of our research design, to make this research more valid.

5.3 Screen Shots or Screen Recorder

A User Experience UX Foraker(Labs) recorder was installed on the iPhone to record every key-stroke and action perform on the screen. Before starting any session, we followed NSD (Committee) guidelines disable mic and camera options.

This tool helped us to perform gesture usability testing on iPhone devices. The application has built-in browser support that allows it to run any website. The limitation of mobile phone accessibility and usability testing is that there is no application which can run a native application inside the device(Wille et al., 2016). That is why heuristic or manual testing can be performed to inspect the accessibility of mobile interface. Use of these methods helped us to track user interaction flow. This tool also helped us to monitor every detail of successful and unsuccessful interactions.This application recorded the sessions and exported them into video format. The screen shots can be shown in Appendix 6.

5.4 Data Analysis

The analysis of text and multimedia information is quite different from the analysis of quantitative data(Lazar et al., 2010b). Our primary focused on getting the real user experience in the data collection session; we conducted semi-structure Interviews, it was then analyzed using grounded theory techniques.

Despite the name, grounded theory is not a theory of qualitative research. It is a method which intends to produce new theory from qualitative data collection during research (Adams, Lunt, & Cairns, 2008). According to Adams et al. (2008), this is not only for qualitative data analysis like interviews, observations and focus groups. It also helps to analyze quantitative data such as questionnaires, logs, and experiments. In our case, the quantitative data came from our usability testing of the gesture. Grounded theory is the form of qualitative research which studies people's experiences as a process, then generates a theory of how that process works. The theory is generated from the data collected during a study, such as an interview or an observation excluded from other sources (Text Book researcher opinions).

That is why we are implementing grounded theory to find new theory and articulate further hypotheses for further study about force touch interactions.

What grounded theory answers in our research are that no theory exists about force touch gestures as alternative input methods for older adults. The study will try to develop a framework that can be used by HCI researcher and practitioner to create Universal Design Gesture by using Force Touch properties. The previous hypothesis we have defined is just for Usability testing. This analysis phase tried to analysis Universal Design Principles and WCAG guidelines with User Experience. For this, we had to recruit elderly participants to create a theoretical sampling to gain insights and knowledge from them about these gesture designs to develop a well-rounded theory. A grounded theory approach was used, focusing on a specific aim.

- To investigate how older user interact with force touch gesture?
- To investigate the role of Universal Design Principles and Accessibility Guideline to overcome functional abilities.
- To develop a theoretical perspective of force touch gesture in older adults.

The qualitative analysis for this prototype will help us to develop categories and explore similarities and differences between the participant's answers and the relationship between answers and task.

The (Lazar et al., 2010b) argues that researcher writes a story about how the theory explains the core process and how all of the categories are related to it as an overall explanation of the theory.

The researcher has to recruit the new group of participants who are similar to the original participants. We then conducted the same interviews with the new participants. The point was to determine the new participants's experience with a process similar to the theory. This helps to test and verify if the theory is accurate. According to (Lazar et al., 2010b) grounded theory consist of four stages.

- Open coding
- Development of concepts
- Grouping concepts into categories
- Formation of theory

5.4.1 Limitation

Apart from the advantages of the grounded theory which (Lazar et al., 2010b) mention in “How to analyzed qualitative data ” they also mention it disadvantages or limitations. According to (Lazar et al., 2010b) It takes lots of time to gather and categorize the data, and analysis can be difficult. This can sometimes create bias and lead to a small sample of user experiences. (Lazar et al., 2010b) Mentioned that sometimes the findings of the research can be influenced by the researcher's preconceived opinions. To overcome bias in this research, we tried to be open- minded for our gesture design, and discovered too many accessibility issues when compared to universal design principles.

5.4.2 Nvivo

The data we have collected is in both numerical and textual form. Both individuals and focus groups were interviewed, and observations were made. According to Lazar et al. (2010b), in a qualitative analysis, the researcher must read the data completely before starting the coding. This strategy helps to develop a general unbiased idea of the data set before focusing on any specific aspects. However, the novice researcher may find it difficult to identify any significant aspect of a developing theme before engaging in open coding. We coped with this issue by using Nvivo software to generate the categories and themes from the data. The methods (Zielke, Zakhidov, Jacob, & Lenox, 2016) for used in their research to analyze qualitative data from Nvivo software measure user experience from Gamers inspired us. “Node” functionality helped us collect and categorize portions of data into nodes that could be compared to the dataset. Using the qualitative analysis software, the researcher can run a query for frequently used words in the interview to find themes.

Nvivo software(Edhlund, 2007) allows easy organization of data collected in different forms, from interviews to papers and articles, and uses queries to identify the connection between the data and locate similarities and differences among the resources.

This software helped us to identify frequently used terms (like accessibility, usability guidelines, and principles for touch-based gesture and research on older adults), code important themes and concepts about user interface design from the resources, and track thoughts throughout the different areas of this project. It helped us to match my methodologies with other authors and themes from the literature review.

In our social science goal, we collected necessary information about age-related characteristics which affect mobile interactions, such as sensory, physical and cognitive ability. We used Nvivo software (Edhlund, 2007) to identify common, age-related problems, which we have discussed already in the literature review. The Nvivo software also helped us to develop a "theoretical model of aging" in the context of force touch interactions. During the literature review, we created nodes title "Characteristics of Ageing", "Design for Ageing," "Elderly Friendly" and "Natural Interface Design" with participant was created and then to compare with participants response with are related to these design principles.

The grounded theory was based on open coding, axial coding, and selective coding (Lazar et al., 2010b). These coding categories were derived directly and inductively from the interview data for force touch gestures.

5.4.3 Open Coding

Researchers use codes and memos to show how various categories are related to each other. We created different "Codes" in data analysis software. This "Codes" functionality helped us to compare qualitative codes, like user feedback to the quantitative data (Usability Testing results). We created attributes of guidelines of accessibility and usability in the software to find the correlation between the nodes and the attributes.After the open coding, we inject Axial coding which helps to create a relationship with codes. Like "how easy is the interface", "flexible", "way to learn" helped us to generate visual diagrams or visual models to explain how the process works. In the 1st stage of analysis, we read the transcripts and determined different categories and themes in the data to get a first impression of the prototype gestures and coded the chunk of text. This helped us to be able to constantly compare the data to the category and memo the coding again and again to drive the categories.

5.4.4 Identifying Coding Categories

We have collected qualitative data from the interviews and have textual answers. Solid qualitative analysis depends on accurately identified the concepts of the coding categories. These were derived directly from the transcripts of (Lazar et al., 2010b) to analyze comments from the older adult participants, specifically their answers to our questions about the force touch gesture user experience after performing the experiment. In total, we collected 80 user comments, and they were arranged in four categories: easiness, discoverable, complex, learnability, memorability.

We asked the elderly participants the question “Which aspects make you like/dislike the force touch gesture.” (Table 3) Seven participants liked the new purpose force to zoom gesture for text. The example comments were “I like new force touch gesture,” “it easy,” “I do not need more help to perform any task with force touch gesture.”

5.5 Development Concept

The practical purpose of this analysis is to confirm and evaluate the force touch gesture with universal design principles and accessibility guidelines. From the initial stage of the data analysis, we tried to be familiar with the data through transcription process. Nvivo software helped us to generate a theme from the data, and thematic analysis from pilot studies to final data collection.

Codes	Concept	Categories	Definition
Physical capabilities mental capabilities sensory capabilities	• Equitable Use. • Flexibility in Use. • Simple and Intuitive Use. • Perceptible Information. • Tolerance for Error. • Low Physical Effort. • Size and Space for Approach and Use.	Universal Design Principles.	What is the user experience with the force touch gestures?
Physical capabilities, mental capabilities, sensory capabilities	• Perceivable • Operable • Understandable • Robust • Conformance	WCAG Guidelines	Understanding the UD principles for touch gestures

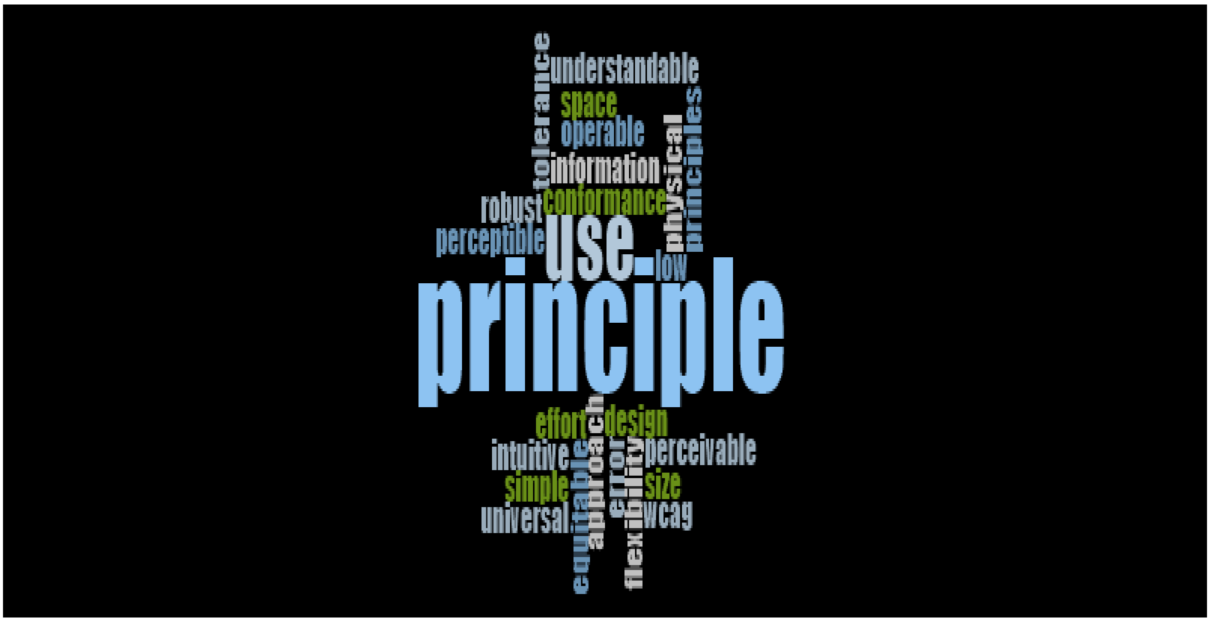
Figure 16 Word Cloud for Force Touch Gesture

Qualitative analysis helps to create a correlation between the force touch gesture feature and design principles for older adults. So, we have purposed some task which can be helpful to design force touch gestures, such as increasing the text size of the fonts with the help of force touch gestures. The second purpose solution is for rotating the picture with a force gesture. The aim of the purposed solution is to give a general direction to the future design of touch screen devices with force touch gestures. According to (Lazar et al., 2010b) identifying coding categories can be a very daunting task for the inexperienced researcher. That is why we have tried to use several sources, like any existing theoretical frameworks on force touch gesture, which were not found in the literature review. For this reason, we incorporated recommendations from past studies, as well as participants' feedback in the data collection process. In this process, we were constantly searching for refining the concept and categories. Which helps us to generate theory for older adults perspective for force touch.

The notes taken from the interview session were tabulated with the principle of Universal Design Principles and WCAG 2.1 Guideline.To assess whether the prototype and newly designed force touch gesture met the needs of older adults. (Lazar et al., 2010a) Stated that content analysis is a systematic approach to handled these issues, this technique help to compressing many words of text into fewer content categories based on the explicit rule of coding. There are two types of content in this study, media and audience content.

5.6 Content Analysis

Media content was stored in an internal folder of the Nvivo software which also contained printed publication of Universal Design Principle, WCAG guidelines and past papers related to this study.



Audience content is the feedback we gathered from the interview session in our experiment design. The information was in text-based note format. Text-based data provided us the main information that was not delivered from the screen capture tool, which we had used for the quantitative purpose.

The Universal Design and WCAG 2.1 principles were used to investigate where these new gestures are following guidelines.

5.7 Analyzing interview data

There are many ways to analyze qualitative data, like analysis the transcript of a sample that has been collected through descriptive measures.

The transcriptions of the interviews were imported into Nvivo which is capable of analyzing both qualitative and quantitative data. The data from the interview was the user experience while using force touch gestures on mobile devices. To process the data into information, user interaction was analyzed with the prototype application which was designed with UD principles and (W3C) WCAG 2.1 Guidelines.

To analyze the answers from the interview and experiment sessions, we used the data analysis methods purposed by (Stephanidis, Antona, & SpringerLink, 2013) for human-computer interaction design methods. Understanding will analyze the questions we have asked of the older adults or interpret the answers.

A theory-driven coding approach was applied to analyze the interview that shows the acceptance level of the participants for new design gestures in mobile interfaces(Edhlund, 2007). The acceptance of the new technology is also called the conceptual framework for obtrusiveness(Reeder et al., 2016), which allows us to examine seven principles of universal design.

The preliminary phase of data collection assisted in refining interview questions for the older adults. In this phase, we encountered a various issue in probing the real user experience from the elderly group. Initially, it was difficult to control the experimental process because the elderly user group was worried, confused, fearful, isolated and frustrated by new technology it also shows in (Pang et al., 2016) study as well. However, some of them were tech-savvy and excited about new interaction designs for mobile. In this process, we are constantly searching for and refining the conceptual construct that may explain the relationship between the concept and categories (XXX).

5.8 Ethical Considerations

The ethics of this research were important, and we followed guidelines from the research ethics committee at (HiOA) and guidelines for research ethics in science and technology by Norwegian National (Committee).

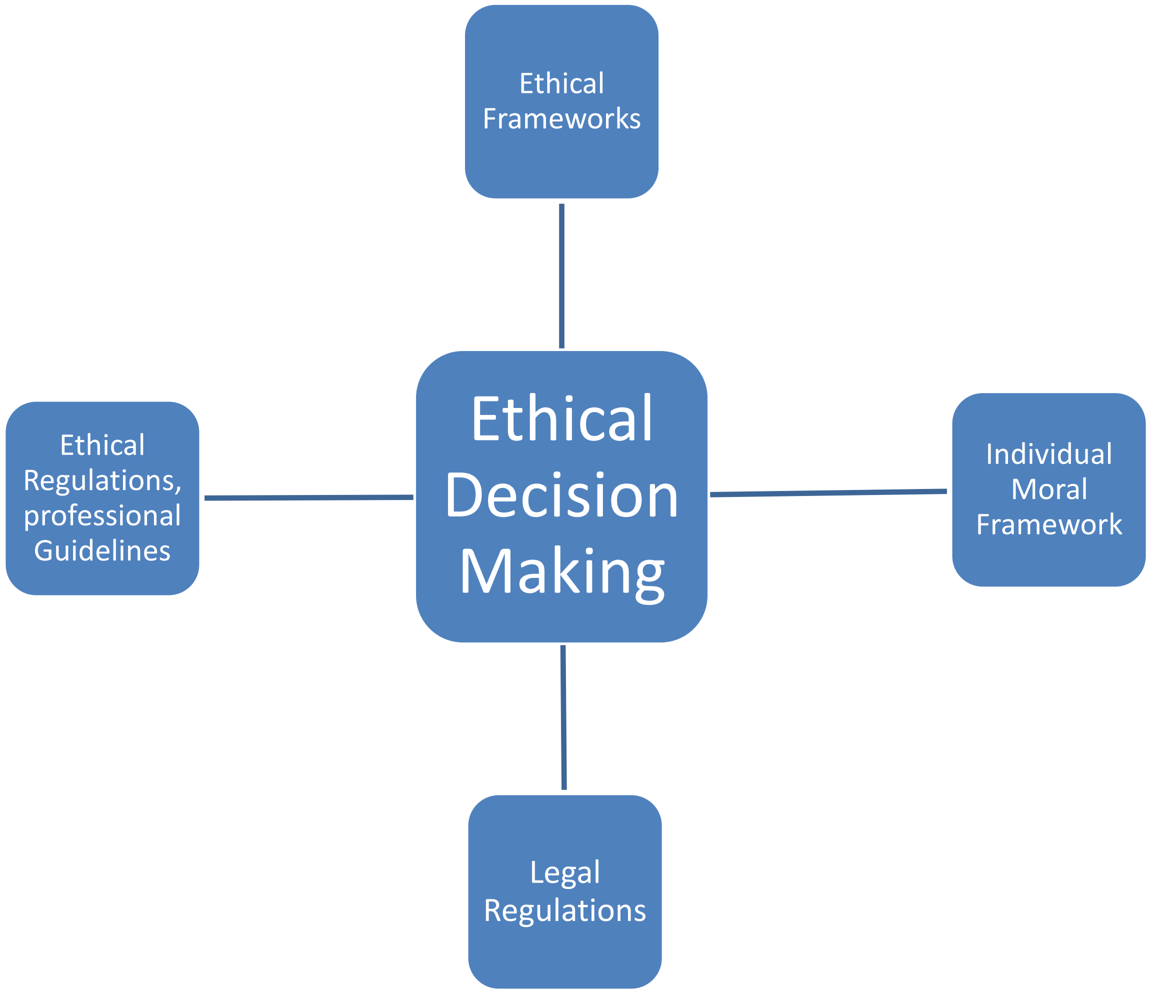


Figure 17 Redesign from "What are qualitative research ethics" (Wiles, 2012)

The author of this book was passionate about encouraging researchers to follow ethical guidelines throughout a research project. This approach helps them to identify ethical issues from the beginning of the project. This book defines an ethical framework and offers guidelines and regulations that guide us on how to oblige these guidelines.

5.8.1 Ethical Framework

The most common ethical framework is based on four principles defined by Dr Rose (Wiles, 2012). These respect the autonomy (split into further categories such as informed consent and confidentially), beneficence, i.e., “do good,” non-maleficence, i.e. “no harm,” and justice which implies an equal distribution of the burdens and benefits of research.

Conducting research on new technology, especially in human-computer interaction is always challenging, particularly when the target group is older adults. Ethical standards are applied to protect the dignity of the respondents in any research. Ethics protocols, guidelines and legislation vary from country to country. In this section, the ethical considerations followed through this study will be elaborated. What, is ethics? Why does it matter in human-computer interaction? How do we maintained human dignity and minimized possible harm to the human subjects in this study?

The (HiOA)research committee is responsible for research activities to maintain high standards of ethics. The Board has issued guidelines for every area of the investigation. The research guidelines were revised and published by the Rector of the HIOA in 2014. The (HiOA) Ethical Guidelines emphasize Integrity, impartiality, independence and openness.

The (HiOA) research ethical guidelines state that a researcher is responsible for the protection of the data collected from the participants and their analysis and that both are stored in a proper way following the Norwegian Centre for research Data (NSD (Committee))standards.

As this research is based on Universal ICT Design, its prototype, documents and appendix sections were made accessible electronically for everyone, including those with visual and fine motor impairments, following general accessibility guidelines.

5.8.2 Privacy, confidentiality, and anonymity

Respecting human dignity, beneficence (i.e. to maximize benefit) and no maleficence (i.e. to minimize harm) are fundamental ethical obligations in research. To achieve this, one should consider various ethical issues and follow ethical principles and guidelines. Everyone deserves the same respect. The target group we choose for this research had different dynamics of ethics as compare to other groups. This age group needs more respect from the family, society, friends and caregivers.

It is the responsibility of the researcher to understand the implications of his or her research and to protect the rights and well-being of the participants regardless of the nature of the study. The following ethical principles have been considered in this research: to respect human dignity and autonomy, to obtain free and informed consent, to be sensitive to vulnerabilities, to minimize the risk of possible harm, to protect privacy, confidentiality, and anonymity, and to consider justice and inclusiveness. These issues are discussed in more detail below.

According to Lazar et al. (2010b) researcher have to make sure that experiments are conducted in a comfortable setting. We have to ensure that all participants have a good day and are in a good mood as well. We gave liberties to all those involved if they felt bored, uncomfortable or in stressed. “Stressed threats” impact performance by raising individual anxiety levels, that is why we had to make sure that the participants' anxiety levels were low so that they could evaluate the design prototype most effectively, but it is tough to identify the anxiety of humans, especially when the researcher is a novice. Although Lazar et al. (2010b) mention that HCI experiments are low risk as compared to other fields like the social sciences, and medical, we make sure that we can minimize any potential for harm by treating our participants properly. In our data collection process, we guarantee the respect of human dignity and autonomy

The(HiOA) research community and NSD (Committee)have guidelines for securing the personal data of participants. In our research, we did not ask any personal details from the participants, including name and date of birth. That is why at this stage, we did not ask for any permission from the NSD(Committee).

5.8.3 Informed consent

This study is about the user experience of older adults on newly designed prototypes for the touch screen. We asked to carry out some experiments on mobile screens. In the pilot studies, we designed a consent form and evaluated the information on the consent form with various research articles and books by (Lazar et al., 2010b) which gave details of how a consent form should be written, and what ethical values every researcher must follow. We mentioned the title and purpose of the study, a description of the procedures, the duration of the whole experiment, risks of harm if any, and benefits from participating in our experiment and we kept the data confidential. We also offered terms for participants' rights and contact information in the case that the participants may have had any concerns or questions after the experiment. Moreover, we finally returned the signed consent form details. We made sure that our consent form fulfilled all the terms suggested according to ethical guidelines and principles.

Each potential participant got an iPhone 6s running our prototype application on it. We started our experiment with 30 minutes, one-on-one sessions to instruct our participants on how to use the force and interact our prototype in 30-minute sessions. The consent form also discussed the goals and objectives of the research and encouraged participants to read the consent form carefully and signed it. We tried to write the consent form in simple terms, so every participant with lower English proficiency levels easily read it. According to the ethical guidelines suggested by NSD(Committee) we made our consent form simple.

According to ethical standards, we gave participants a prototype review. Before signing the consent form, we allowed participants to interact with the prototype to get familiarize themselves with the applications and gestures. We also offered 20-minute sessions to familiarize the participants with the prototype, and ask any questions.

We found that older adults were reluctant to read the consent form and signed it without reading.

5.8.4 Trust and Rapport

The trust and rapport are the most important relationships in qualitative research. We tried to follow the principle "To Probe or not to Probe." The methods suggested by (Kuha, Butt, Katsikatsou, & Skinner, 2017) give an overview of how to tackle participants when they do not know about non-responsive participants. These methodologies are suited for surveys, but in our research, we faced this issue because the force touch technology is new and the elderly user group is inexperienced with it. Sometimes probing influences research and create bias but in our case, some questions were very necessary to probe. Few of the elderly participants answered "don't know" in the initial stage of the interview session. The probe helped us to encourage interviewees to provide more details and explanations for the questions we asked during interviews. We have marked those questions in each interview where we needed to probe the answer, to reduce bias in our research.

6 Findings

The chapter provides the details of the findings. It includes participant feedback for the touch screen gestures, emergent themes, and discussion points. Nvivo was used to find commonly occurring themes in the data and 11 nodes, grouping responses in ways that invoked engagement.

User Testing

The main finding from this study are:

- To enhance the elderly people user experienced HCI researcher and designer pay special attention to Universal Design Principles.
- Priorities user needs before designing any new gestures by collecting information from the literature review especially from the past studies based on Universal Design and Design for Ageing Guidelines.

6.1 Hypotheses Tested

An Experiment normally starts with a research hypothesis(Lazar et al., 2010b). The force touch-based gesture can be evaluated with many guidelines like WCAG, UD, and UCD, but our aim is to define a very precise problem statement that can help us to investigate during experimental studies.

Force touch user interface was used as an alternative interaction method in our prototype application and works precisely as we had planned in our hypothesized design phase. The following research question was asked to test the hypothesis.

H0: There is no difference in user satisfaction concerning zooming usability between multi-touch gestures and force touch gestures

H1: The force touch gesture has higher user satisfaction concerning zooming usability due to it being faster than a multi-touch gesture.

Our first hypothesis is that we may achieve higher user satisfaction for force touch gestures if we follow accessibility and usability guidelines. As an advantage of this approach, we achieved our aim, and we have found that user satisfaction in prototype testing shows that force touch gesture has higher user satisfaction for the force-to-zoom and force-to-rotate gesture. Force touch gestures have less accessibility issue than pinch-to-zoom and pinch-to-rotate gesture. However, for this kind of usability testing the sample size should be more than 20 people according to Lazar et al. (2010b) hypothesis testing wth typical independent variables in HCI research where research compare different technology like in our case such as force touch vs. multi-touch are depended on user satisfaction and efficiency. Normally this kind of studies are used Likert-scale to measure user satisfaction, but in our case, we have collected qualitative data for user satisfaction.

In term of time performance, we have observed that force-to-zoom for have low efficiency than pinch-to-zoom gesture on the other hand force-to-rotate has higher efficiency than pinch to rotate gestures. The other categories of a variable like easy of learning, cognitive and physical demands were qualitatively analyzed. The answer were probe and interpret in Univerdsal Desgn Principles and WCAG Guidelines.

6.2 Universal Design Principle

6.2.1 PRINCIPLE ONE: Equitable Use

The design is useful and marketable to people with diverse abilities.

Guidelines:1a. Provide the same means of use for all users: identical whenever possible; equivalent when not.

> The force touch gesture was design with accessibility in mind. One of the interview questions asked that "In your force touch experience, have you got any difficulties while performing tasks."

For 6 out of 9 participants were observed to perform force touch gesture without any difficulties? However, 3 participants feel difficult to perform these gesture and need more training to understand how this gesture works. This gesture fulfilled (W3C)WCAG 2.1 to provide same interaction methods for everyone. After evaluation, that force touch gesture can help people with a motor impairment to use these gestures without the need of Assistive Technology or special designed. For example, this gesture can provide an alternative way to provide "Keyboard Only User" to skip to main content with force touch interaction.

1b. Avoid segregating or stigmatizing any users.

This gesture were not designed as a specialized design for elderly that is why we have observed that this principle was followed by our prototype.

1d. Make the design appealing to all users.

Our text zoom gestures were appealing to some users. It was observed that older adults have difficulties enlarging the text size. Usability testing also shows that this gesture has much greater efficiency than the two-finger pinch gesture. (Mihajlov et al., 2014) Mention that older adults find difficulties rotating an object on touch screens since this gesture demands a higher level of physical coordinatization. In a purposed solution, we observed that there could be an easier way to rotate the object with buttons.

6.2.2 PRINCIPLE TWO: Flexibility in Use

The design accommodates a broad range of individual preferences and abilities.

Guidelines:2a. Provide choice in methods of use.

One of the questions asked in the interview session was "Which task was easy to perform and which one hard?"

Seven out of nine participants think that pinch-to-zoom(old method) was easy for zooming for zoom and six out of nine participants preferred force-to-rotate over the old method.

The force touch gesture is designed to provide an alternative method of interaction with smartphones. Due to the small size of the screens, it was observed that older people have difficulties due to dexterity, arthritis and visual impairment. That is why we have noted that both texts are enlarging and rotating gestures try to resolve this issue by providing an alternative way of interaction.

2b. Accommodate right- or left-handed access and use.

It was observed in the experiment session that these gestures accommodate right and left-hand access for older adults, but the majority of users prefer their default hand to perform the gestures. The eight out of nine participants were right handed. During the experiment session, we asked the participants about their hand preference because it is a major factor for ease of use of the interface. We have not observed any difficulties based on hand preference. The newly purposed gestures are designed in a natural way so both right and left handed users can perform tasks easily.

Figure 18 Right and Left-Hand Usage

2c. Facilitate the user's accuracy and precision.

The basic aim of 3D-touch gestures is to provide shortcuts and a fast paced environment. In the literature, we found that older adults have difficulties with the fast-paced environment of technologies due to limited cognitive abilities. We observed that some of the very old participants (age 77 to 82) failed to perform the rotating gesture due to lack of experience with mobile devices, and a lack of knowledge about touch gestures.

2d. Provide adaptability to the user's pace.

We have not tested these gesture to provide any shortcuts.

6.2.1 Principle Three: Simple and Intuitive Use.

One of the interview questions was “Do you think newly designed gesture helps you to increase font size easily compare to your old conventional methods?”

Five out of nine participants believe that it was easy, but they have an issue with it discoverability. Therefore they want improvement in discoverability of the gesture type.

Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level

3a. Eliminate unnecessary complexity.

The literature studies show that the pinch gesture for zooming a picture or text size is challenging for people who have a fine motor, cognitive and sensory-perceptual disabilities(Light & McNaughton, 2014). To eliminate the complexity of two finger pinch or rotate gestures, we tried to get user experience by providing an alternate way of performing these tasks with one finger.

3b. Be consistent with user expectations and intuition.

We have observed that these gestures were surprising for some participants because they were not aware of this new interaction method. Therefore, we have noted that developers need to make a gesture with consistency in design, so older adults do not need to learn from scratch to use force gestures. However, these gestures require following disclosure which means researcher in HCI introduce new gesture to the participant with the most important option this gesture can perform. That is we made a tutorial to introduced these gesture to older adults. This method helps us to get insight knowledge what this targeted group thinks about this upcoming interaction technique in mobile.

3c. Accommodate a broad range of literacy and language skills.

3d. Arrange information consistent with its importance.

3e. Provide effective prompting and feedback during and after task completion.

This is the first time touch screen gestures are providing haptic motor vibration in mobile devices. This feature increases are pointing accuracy for older adults, which helps to provide an alternative way of interaction for users who can see. (Weiss et al., 2011) Studies indicate that haptic feedback increases both pointing accuracy and task time compared to other mainstream multi-touch gestures. In our purposed design gesture, we have not provided any tactile feedback to inform the user of task completion. Moreover, these gestures produce vibrations while pressing the button or touch the screen.

6.2.2 PRINCIPLE FOUR: Perceptible Information

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

4a. Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information.

The literature review also shows that the aging process influences cognitive abilities. This means that newly designed gestures should be easy to learn, and memorable. We tried to develop new gestures in term of reducing memory load. In the comparison test, we found that the force touch gesture for increasing the text size was easy to learn for most of the participants, but they had issues reducing the text to its original size. However, as compared to common multi-touch gestures, participants preferred force touch gestures because the haptic feedback helped them to perform the tasks more precisely and accurately.

4b. Provide adequate contrast between essential information and its surroundings.

4c. Maximize "legibility" of essential information.

4d. Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions).

4e. Provide compatibility with a variety of techniques or devices used by people with sensory limitations.

In the interview session, we get positive feedback from the participant for interacting with force touch gesture. A user who found pinch, double tap, drag, flick spread gesture difficult to use. Force touch gesture give user alternative way of interacting. People with sensory limitations often used Assistive Technology.

Six out of nine participants used screen magnification for reading they suggested that if a force-to-zoom gesture has improved discoverability, it can help them to read articles without any ATs.

6.2.3 PRINCIPLE FIVE: Tolerance for Error

The design minimizes hazards and the adverse consequences of accidental or unintended actions.

5a. Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded.

The drawback of the force-to-zoom gesture is it has no visual feedback that's why it could hard to discoverable, but it can reduce error rate because it has haptic feedback in it. These gestures prevent older adults for un-intention touch on the screen.

5b. Provide warnings of hazards and errors.

5c. Provide fail safe features.

5d. Discourage unconscious action in tasks that require vigilance.

In the literature review (Taher et al., 2014) shows that force touch gestures can reduce the unconscious action with haptic or haptic feedback in the gesture.

Six out of nine participants express their concern that unconscious touch in old methods creates difficulties for them. They like the idea to reduce these error by force touch, so they will not lose in touch screen environment.

6.2.4 PRINCIPLE SIX: Low Physical Effort

The design can be used efficiently and comfortably and with a minimum of fatigue.

6a. Allow user to maintain a neutral body position

It is observed in many studies in the literature review older adults can found pinch-to-zoom gesture difficult because they are not able to apply pinch gesture due to fatigue(Liang & Lee, 2016). Older adults feel uncomfortable to apply pinch gesture on the touch screen. In this study, we provide them an alternative way of pinch gesture. The overall participants show satisfaction with force touch gestures, but it needs more research we different task and devices.

6b. Use reasonable operating forces.

The force touch gesture is design for applying pressure on the touch screen. Studies show that physical abilities of older adults limited with the passage of time. In our experiments, we have not found any participants who were not able to apply pressure on the screen. However, this gesture will be problematic for people who cannot hold the mobile due to seizure or other impairments which affect touch interactions. This study needs more participants who have

6c. Minimize repetitive actions.

6d. Minimize sustained physical effort.

6.2.5 Principle 7: Size and Space for Approach and Use.

Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

7a. Provide a clear line of sight to important elements for any seated or standing user.

These gestures have not tested with an exceptional condition like walking, driving, and sleeping. Such experiments may be useful in the design and evaluating of future of force-touch gesture in term of usability and accessibility aspects.

7b. Make reach to all components comfortable for any seated or standing user.

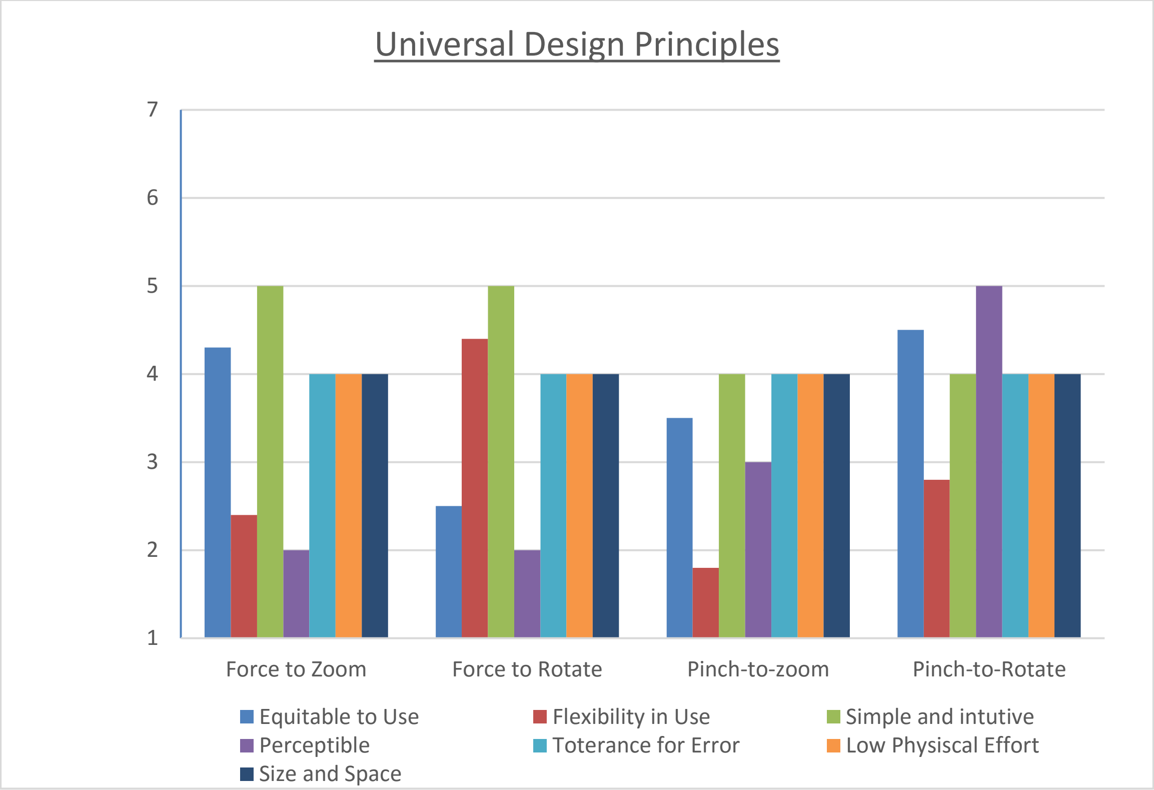
We have conducted nine experiments, but our focused were on collecting qualitative data like user perception about this newly introduce gestures that's why we have not made any comparison of seated Vs standing user performance while using these gesture. In future work, we will probe how this gestures will be helpful when these type of gesture is available for commercialization. Evaluating these gesture for the more exceptional condition would be good.

7c. Accommodate variations in hand and grip size.

Most of the older adults were easily grip the iPhone 6s. We have not found any issue to grip the phone regarding its size. However, due to small sample size, we cannot see any participant who was suffering from a seizure. According to (W3C) WCAG 2.1, the gesture interface should be mindful for a user like elderly who has seizures issue.

7d. Provide adequate space for the use of assistive devices or personal assistance.

When we tested these gestures with a blind user, we found that there are lots of accessibility issues when a user wants to use these gestures with assistive technology like a screen reader. However, none of our elderly grouped users used any Assistive Technology like screen reader or stylus. Furthermore, most of them use screen magnifier to increase the text size. Our one purpose gesture is for increasing the text size that is we have not conducted any experiment on the screen magnifier. A future iteration of this study should aim for test these gesture with more Assistive Technologies with a significant amount of participants.



Universal Design Principles
7
6
5
4
3
2
1
Force to Zoom
Force to Rotate
Pinch-to-zoom
Pinch-to-Rotate
Equitable to Use
Flexibility in Use
Simple and intutive
Perceptible
Toterance for Error
Low Physiscal Effort
Size and Space

Findings from the interviews reveal that older adults truly believe that force touch gesture interaction has a potential to become mainstream gestures, like pinch-to-zoom, tap, double tap, etc. in future. Although some users find accessibility issues, like discoverability and memorability, they still think they want to use these gestures. During the interview sessions, we asked the participants about their like and dislike of the force gesture. Most of them reported that the force-to-zoom gesture is undiscoverable. However, most of them liked this gesture because it is easy as compare to the pinc-rotate gesture. Their feedback about other purpose gesture for force-to-zoom was highly recommended. They recommended a sign on the button for rotation to help them learn quickly and remember. We have noticed that we have violated WCAG principle 4 “understandable.” According to (W3C) guidelines, the developer must provide clear instructions for custom gestures. We have provided the instructions in our manual. We also gave clear instructions on how to use these gestures and alternative gestures in our user manual see Appendix 5. According to this principle, an instruction manual about “how to use gestures ” should be available for whenever a user is stuck and needs them. Our observations show that Apple iPhone does not have instructions about the usage of its new interaction methods for “3D-Touch,” also known as force touch.

According to WCAG(W3C) guideline principle, “operable,” custom gestures or new design gestures can be simple to use, such as a tap with one finger. We have tested some built-in (3D-Touch)gestures like “Quick Action” and “Peek and Pop” with assistive technology like a screen reader. The force touch gesture is undiscoverable for blind users. One of our participants who is an expert user and has been using Apple devices for more than five years reported that he did not know about the 3D-touch gesture before this experiment. The main reason behind it is a lack of information in the user's manual and about this gesture by the manufacturer. For screen reader users, the gesture can read everything. It is observed that force touch is inaccessible in various interaction methods such as browsing a picture from the gallery or accessing a hyperlink. It is reported that these gestures are undiscoverable for a blind user. However, on the other hand, they can be utilized in various ways. For the blind user, skip navigation is important to access the main content of the (webaim.) Screen reader user generally must navigate a long list of navigation links, sub-list, images, site search and menus and other elements before ever arriving at the main content. Here, the force touch gesture can be use to navigate directly to the content that the user wants to reach.

6.3 Conclusion

One of the key findings from our technology probe of force touch gestures with inclusive design and research methodology was that participants were amazed by force touch gestures. It became apparent that everyone wants force touch gestures to perform more operations than those we have proposed in our experiments.

The dissertation study used a life course perspective to examine the role of elderly friendly gestures in Human-Computer interactions and was analyzed using grounded theory techniques. The user experience for force touch gestures highlighted the Universal Design Principle and Accessibility guidelines.

Studies on three-dimensional gestures with experimental design enabled a controlled investigation of the Universal Design principles and WCAG 2.1 Guidelines with user experience from older adults.

After gaining the user experience from the older adults, we have seen that they have a unique perspective on technology use. Most of them are novices, and less experienced with touch screen influences in user testing.

This research will be based on 18 months of universal design efforts to determine the methods of interaction on the touch screens with pressure and sense gestures. This study will help researcher and UX designers make mobile gestures more intuitive and natural. This work will contribute to human-computer interaction by evaluating and developing gestures for the widest range of users, including older adults. This study will also try to fill the gap of demands of user awareness concerning easy interaction methods with mobile technology. Most of the users are not aware of gestures available into their mobile devices. The purposed interaction method can help researchers to refine and evaluate pressure based gesture with (W3C) and other practice community guidelines.

The main limitation of this research was to find older adults who used iPhones or touch screen phones. A secondary limitation was speaking English with them. Many elderly Norwegian people are not comfortable with the English language, so it was hard to communicate clearly with them. As a researcher, I am also aware that older people have particular needs that may be different from the needs of younger people, and this difference may have influenced the findings of the study.

The number of participants also proved to be a limitation. I think that including more participants with some visual or fine motor impairments would be beneficial for testing the hypothesis questions related to "Design for All." Second, we should include more female participants to address Universal Design principle 3, 5,6 and 7.

The third goals of the gesture probe were to make sure that force touch gestures can be accessible for older adults. The social goal was to collect data about force touch technology and its use in different mobile interaction, especially for older adults. The second goal, known as the engineering goal, was to test our Wizard-of-Oz to simulate force touch gestures with the user requirements which we collected in the first goal. This session helped us to find real life problems faced by older adults while interacting with force touch technology. However, also solved them by implementing the Universal Design Principle and WCAG guidelines on our purposed solutions. This goal helped us to achieved our next goal which was "Designed Goal." We designed some gesture that was suitable for older adults for daily mobile computing. We designed force touch gestures to increase font size and a force-to-zoom gesture. The second purposed solution was to rotate the screen by applying force to the touch button. These gestures opened a new gate for researchers to investigate new interaction possibilities and brought new ideas for how these gestures can make mobile interaction more holistic in the future.

6.4 Discussion

Currently, the force touch gesture is at the beginning of its development in major mobile device manufacturing. Apple (3D-Touch, 2016) introduced mainstream force gestures in their laptop devices, but as of now, there are still a limited number of gestures available for mobile devices. Still, Android just introduced long hold gestures which are alternatives for force touch gesture, From this study and the resulting classifications, we can understand that accessibility and usability issues can be problematic for elderly friendly mobile gesture interfaces if developers and designers do not follow (W3C) WCAG 2.1 and Universal Design Principles.

Previous research on the behaviors touch screen use emphasized usability testing regarding calculating dwell time or effectiveness like time-performance, user satisfaction percentage and how fast users can learn the new gesture. This study focused more on qualitative study methods, which can help us to determine the depth of the data as compared to previous studies, which were more focused on the breadth of the data as a statistical test for collecting evidence to the supported hypothesis.

The strength of this research is that it is based on "inclusive research" like we conducted both qualitative and quantitative studies in the form of interviews and observation. These can help to determine usability and accessibility problems, which can motivate users to interact with systems more easily. The past research on the gesture design was mostly based on one methodology either design thinking or any scientific methods. In this study we tried to apply both in the early phase, we applied design thinking approach to understanding the problems of the elderly user, and then we have tested our prototype gesture in a real environment to achieve this aim we set our goals in "Technology Probe" methodology. We tried to apply new research methodology for this new interaction method in HCI. This means that (3D-Touch) or force touch gesture give the opportunities to the researcher to build new interaction for touch screen in mobile but researcher keep in mind to develop this technology with accessibility in mind.

We tried to adopt new research strategies like "Technology Probing" which goals to explore new technologies with user perspective for emerging technologies it will help future researcher and practitioners to generate "Theoretical model of Ageing " after analyzing the qualitative data. However, this theory needs more experiments and big sample size to collect the feedback from the user. Then it requires expertise to analysis data with qualitative software like Nvivo.

This study will also help to include our recommendations for force touch properties in WCAG 2.1 guidelines. These properties need a more concise guideline for making new gesture more accessible for older adults. The one recommendation could be new force touch gestures should have alternative text for touch properties.

In summary, the technology probing of force touch gesture will be beneficial to future studies which aim to provide more interaction methods by using force touch gesture with more improvement. The future studies can make these gesture with a more broader perspective to include participants for another group like blind and people who have any motor impairment.

Also, these gestures will use with multi-finger force gesture to develop more interaction methods with in touch screen. Potentially multi-fingers force touch gesture will blind user to improve their user experience with screen readers. These new gesture interactions methods have a capability to increase accessibility as compare to old gesture.

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8 Appendix 1:

8.1 Recruitment Scripts

When corresponding with a potential participant, I used the following script.

Hello _____________(Name)____________,

My name is Rao Muhammad Danial Ali and I am a student at the Master Student in Universal ICT Design at HIOA.

I was speaking to ___ (Name)____ recently, and he/she suggested that I contact you because you may be interested in learning about a study I am doing and that you may be willing to be a participant in the study.

I am performing a study on user experienced the Elder Adults who used a smartphone in their daily life. I aim of this study to find out accessibility issue in the multi-touch and 3D-touch gestures. 3D touch gesture is newly introduced in Apple iPhone, and it works when participant applies some pressure on the touch screen. If you are interested in hearing more, I would be happy to share more information with you at this time.

(If the individual is not interested, I will thank them for their time, provide my name and contact information if he/she would like it, and hang up. If they are interested in learning more, I will continue with the script.)

8.2 Appendix 2:

You are invited to take part in a research study of how users interact with newly Design Prototype for Mobile Devices. Please read this form carefully and ask any questions you may have before agreeing to take part in the study.

What the study is about: The purpose of this study is to learn how users interact with the touch interface by attempting to complete assigned task. The touch screen interaction is very common nowadays we designed a new interface which allows you put some pressure on the screen. We will record screen recording, but it cannot record your voice or video. It just records your touch targets on the screen.

What we will ask you to do: If you agree to be in this study, we will ask you

To use a mobile phone and perform some touch gestures through an interactive website. Which is our prototype of the interface? As you go through the tasks, we would like you to think out loud. We may ask you additional questions about your interpretation or intuition about what functions our tools provide. The purpose of this experiment is not to check your ability it is about to gather information to improve design of the force touch support applications.

Task

You have to read a text on the screen after increasing the text size to an appropriate level which suits you.

You have to rotate the image to a certain point and hold its position for a while.

Compensation:

*Taking part is voluntary:*Taking part in this study is completely voluntary. You may skip any tasks that you do not want to complete or attempt. If you decide not to take part or to skip some of the tasks, it will not affect your current or future relationship with Oslo and Akershus University College. If you decide to take part, you are free to withdraw at any time.

*Your answers will be confidential.*The Records of this study will be kept private. In any report, we make public we will not include any information that will make it possible to identify you. Research records will be kept in a locked file; only the researchers will have access to the records.

I confirm that I have read and understood the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected.

I agree to take part in the above study.

Name of Participant	Date	Signature
Name of the researcher		

8.3 Appendix 3

Interview Guide

8.3.1 Section 2: Experiment

This experiment is about force touch gestures on the touch screen. I just observed how you perform some task on my prototype.(Details about experiment and tasks)

8.3.2 Rapport Establishment

Danial:

Qualitative Semi-structure interview on Mobile Gestures

Hello, my name is Danial, and I would like to ask you some questions regarding the Mobile phone gestures. This interview is divided into four sections -

Section 1: Introduction and user experience,

Section 2: Experiment

Section 3: Security and privacy,

Section 4: Summarization.

During the interview, I would like to discuss the following topics: Your mobile experience to perform some task, advantages, and disadvantages of the touch screen, and difficulties making the touch gestures.

8.3.3 Section 1: Introduction and User experience

Are you used mobile for daily routine?

How long have you been, using touch screen mobiles?

Are you familiar with touch gestures? Do you perform touch gestures like Swap, Pinch, and zoom?

Which device do you use for Reading newspaper?

How much do you spent on mobile daily?

Smart Phone Interaction

I would like to begin by getting a sense of what smartphone mean to you

- How would you define “Touch Gestures.”

8.3.4 Section 3: User Experienced

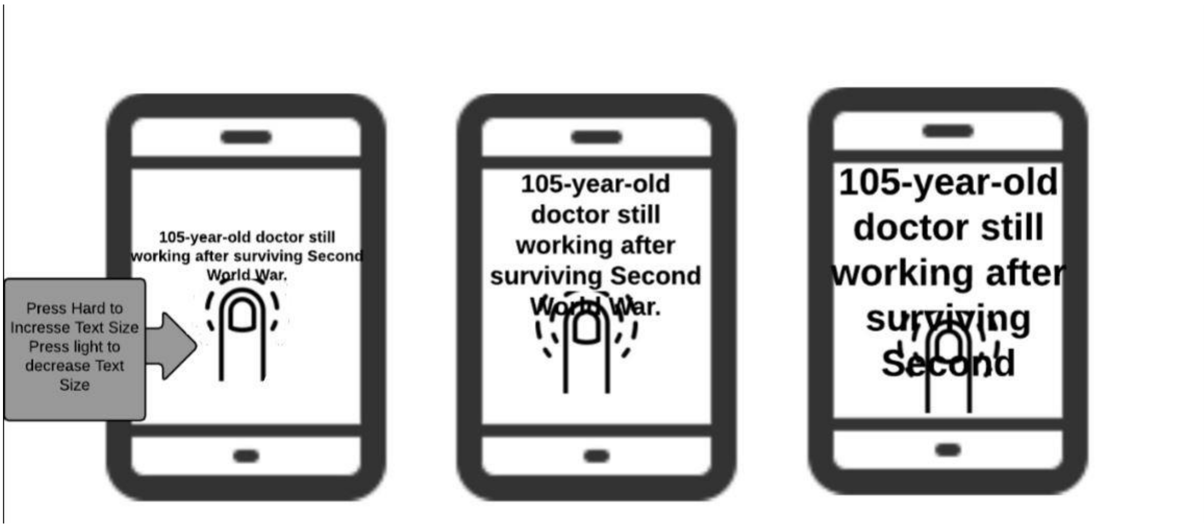
- In your force touch experience, have you got any difficulties while performing tasks?
- Which task was easy to perform and which one hard?
- Do you think newly designed gesture helps you to increase font size and image size easily compare to your old conventional methods?
- If yes/no
- The newly design gesture are easily to learn?
- Do you find any difficulty to perform force on the screen?
- Did you manage to use force touch gestures?
- Did you feel that you could solve your tasks easily and without the help of others?

8.3.5 Section 4: Summarize

Improvement Suggestions - Do you have general suggestions that make these gesture more easy to use?

8.4 Appendix 5

8.4.1 User Manual



8.4.2 Step 1:

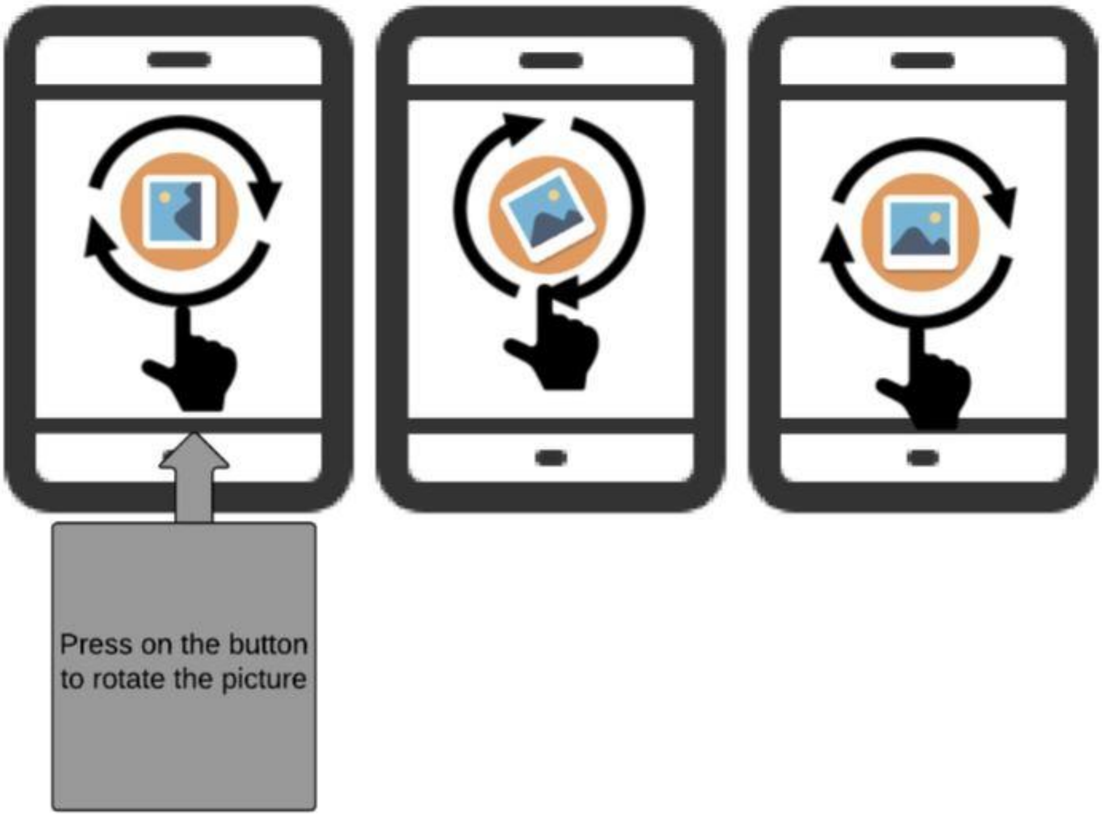
On the text field, you can press hard by tapping on the text. The amount of pressure you increase on the screen the text will increase accordingly.

8.4.3 Step 2:

You can use two fingers to pinch on the touchscreen to increase the size of the text.

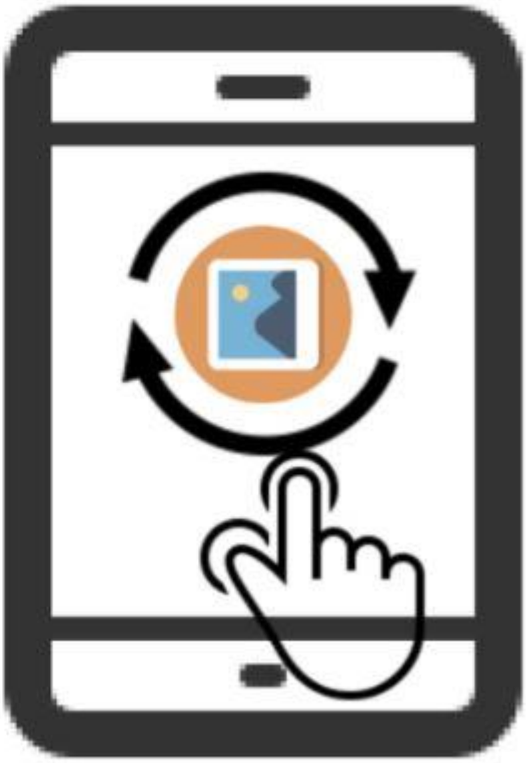
8.4.4 Step 3:

You can again press hard on the button to rotate the picture. As mush you can exert the pressure on the button, the image will rotate the same speed accordingly.



8.4.5 Step 4:

You can use your two fingers to rotate the picture according to the picture below.



8.5 Appendix 6

8.5.1 Screen Capture

Figure 19 Force-to-zoom

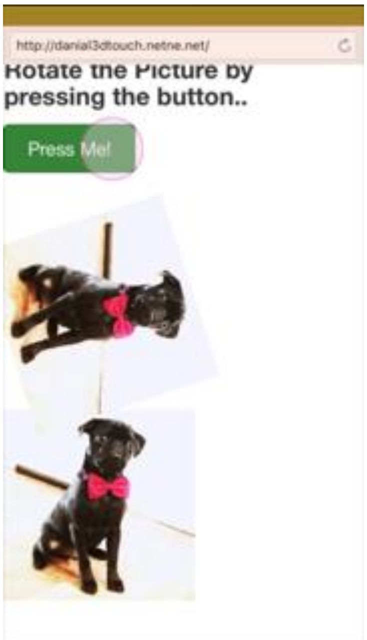


Figure 20 Force-to-rotate